MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

A CHALLENGE

The problem of universal well-being offers a challenge and a call to duty that the engineer may not refuse. The primary conditions and responsibility for universal well-being now rest upon his shoulders, and the engineer does not like to be concerned with a half-finished "job." There is good reason to believe he will do his share of work in attaining the ultimate results desired. Already there are significant signs that he has accepted this duty.

. . . . Unless we can in some manner change our industrial system so that we can more nearly attain universal well-being and distribute the fruits of our industry more equitably, we have no reason for believing that our civilization shall endure, and its bones will surely strew the shores of time with those of the great civilizations that have preceded us.

DEXTER S. KIMBALL

JANUARY 1923

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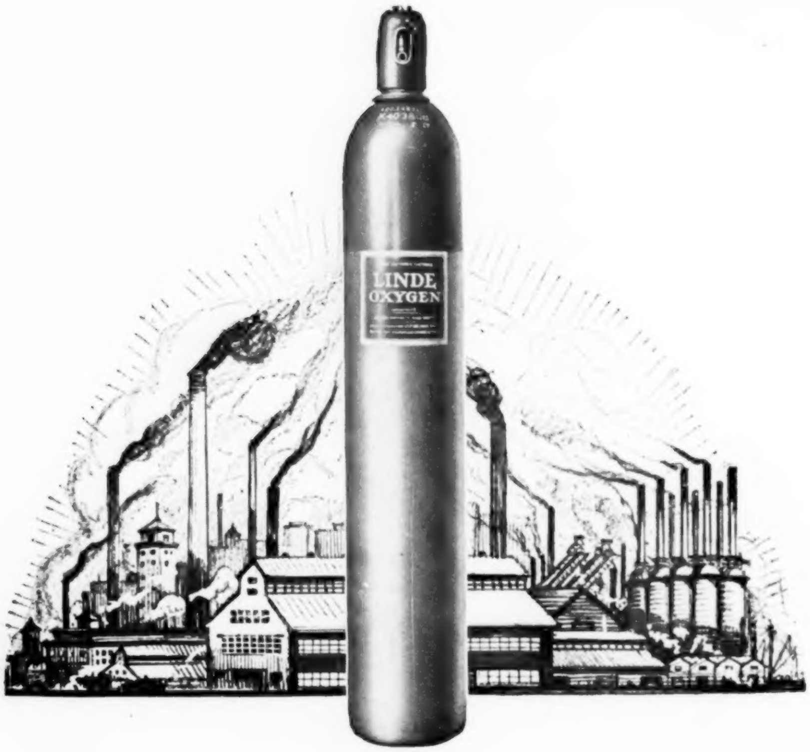

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DEPARTMENTAL

ADVERTISING

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Contributors and Contributions

National Leadership

That universal well-being, depending primarily upon the industrial background, may be attained under the leadership of the engineer, was the sentiment of the presidential address of Dexter S. Kimball at the Annual Meeting of the A.S.M.E.

Since his graduation from Leland Stanford, Jr. University in 1896, with the exception of a few years spent with various engineering firms, Dean Kimball has been a member of the Cornell faculty. Until 1915 he was professor of machine design and construction, and since that time he has occupied the chair of industrial engineering. He became dean of the College of Engineering in 1920.

He is co-author with John H. Barr of Elements of Machine Design, and author of Industrial Education, Principles of Industrial Organization, Elements of Cost Finding, and Plant Management, as well as of many contributions to the technical press.

Engineering and Economics

At a joint meeting of the American Economic Association and the A.S.M.E. during the Annual Meeting two papers on engineering and economics were presented. Wesley C. Mitchell who spoke on Making Goods and Making Money, is director of research at the National Bureau of Economic Research and professor of economics at Columbia University.

Dr. Mitchell was graduated from the University of Chicago in 1896 and studied at the Universities of Halle and Vienna in 1897 and 1898. He was instructor in economics at the University of Chicago for two years and in 1902 went to the University of California as professor of political economy. He joined the faculty of Columbia University in 1913.

E. M. Herr, who is president of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., clearly defined the manager's responsibilities in relation to the human problem in industry. Mr. Herr is a graduate of the Sheffield Scientific School, and has received degrees of D.Sc. from Franklin and Marshall College and A.M. from Yale University. He is a member of the corporation of the latter institution. Previous to his present position, which he assumed in 1911, Mr. Herr was connected in various capacities with several railway lines in the northwestern United States, with the Grant Locomotive Works in Chicago, and with the Westinghouse Air Brake Co.

Symposium on Stokers

Three papers presented at a joint meeting of the Stoker Manufacturers' Association and the A.S.M.E. during the Annual Meeting are abstracted in this issue. The authors of these articles are men of long experience in stoker work. Thomas A. Marsh, an Englishman by birth, is a graduate of the University of Illinois and since 1906 has been connected with the Green Engineering Co. at East Chicago, Ind.

George I. Bouton, for seven years chief engineer for the Murphy Iron Works, Detroit, Mich., is a graduate of Washington University. He spent seven years as engineer for Bryan & Humphrey in St. Louis, nine with the Heine Safety Boiler Co., and four in consulting mechanical engineering in New York.

Howard F. Lawrence has devoted the most of his time since his graduation from Stevens Institute to the development, operation, and general design of underfeed stokers, with particular reference to the Taylor stoker.

Tests of a Type "W" Stirling Boiler

Using information obtained from extensive tests conducted during 1921 on a large Type "W" Stirling boiler at the Connors Creek power house of The Detroit Edison Co., seventeen of these large boilers have been rebaffled with a resulting improvement in boiler-plant efficiency and an increase in the degree of superheat of the steam. These tests were described in a paper presented at the A.S.M.E. Annual Meeting and included in this issue. Its author, Paul W. Thompson, has been connected with the Detroit Edison Co. since October, 1913, as technical director of the operation of generating plants. Mr. Thompson is a graduate of Cornell where he taught heat-power engineering for two years.

Power Required for Cutting Metal

Fred A. Parsons, chief engineer of the Kempsmith Milling Machine Co., Milwaukee, Wis., through the Machine Shop Division of the A.S.M.E., contributed to the Annual Meeting a paper giving the results of an investigation to determine the fundamental laws governing milling, turning, planing, and drilling operations on the various metals and alloys used in machine construction. This paper contains formulas and tables by means of which the power required to machine metal in any given case may be calculated.

Mr. Parsons has been connected with the Kempsmith Milling Machine Co. since 1911, with the exception of a few months when he was machine designer for the Cincinnati Milling Machine Co. His early experience was obtained in various shops in Kalamazoo and in the metal plant of the Baker-Vawter Co. at Benton Harbor, Mich.

Testing Involute Spur Gears

The Machine Shop Division of the Society also contributed to the Annual Meeting a paper by Mansfield Estabrook reviewing some of the more commonly used methods of testing or inspecting spur gears. Mr. Estabrook was graduated from Harvard in 1899 with a B.A. degree and from the Massachusetts Institute of Technology in 1901 with the degree of S.B. in mechanical engineering. Since his graduation he has been with the Niles-Bement-Pond Co., except during the war, when he was a captain in the Ordnance Department, connected with the inspection of small arms.

Lumber-Cutting Waste and Production

This issue contains an article outlining the principles and application of a wage-incentive plan which has been successfully operated to reduce lumber-cutting waste and increase production. Its author, Carle M. Bigelow, chief engineer for Cooley & Marvin Co., Boston, Mass., since 1916, is a graduate of Rhode Island State College. From 1912 to 1916 he was in the employ of the Glenlyon Dye Works, Saylesville, R. I.

The Engineering Index

Attention is called to two important changes in regard to The Engineering Index: the location of the main portion at the end of the advertising section and the supplementary list of last-moment items on page 82. The reasons for these changes will be found on the editorial pages.

MECHANICAL ENGINEERING

Volume 45 January, 1923 No. 1

National Leadership[1]

By DEXTER S. KIMBALL, ITHACA, N. Y.

THE ultimate criterion by which any civilization will be judged will not be its armies or navies, its great edifices nor its wealth, but the degree of well-being—physical, mental and spiritual—that it bestows upon its people. This problem of universal well-being is most ancient and comes naturally from man's desire to enjoy the good things of life before he goes hence. The attainment of even an approximate realization of this desire was denied to all the old handicraft civilizations that preceded the present era. It does not appear to be possible to create by handicraft methods sufficient worldly comforts to support a great nation without having the larger part of the population work as menials with little or no mental development. The national ideals of all handicraft nations are, therefore, those of necessity and hold little hope of physical comfort this side of the grave.

Past-President Dexter S. Kimball

The Problem of Universal Well-Being

But there has been born to us in these latter days a hope that this old desire may yet be realized, and this hope comes to us through the use of modern methods of production. Our civilization differs from those that have gone before, and from some that exist even today, only in one important particular. Our philosophy and our religions are built up for the most part of beliefs inherited from our forefathers, but our power to produce the necessities of life, to feed, clothe, and house the multitude, stands out as a thing apart and unlike anything that has as yet appeared on this earth so far as we have record. This power has come to us through the use of what we are pleased to call the "scientific method," by which we aim finally to replace the words "I think" with the words "I know" in all of our mundane activities. Our success in the use of this method in conquering unfriendly nature and turning her resources to our use has been most remarkable, and as it has become increasingly clear that physical, mental, and spiritual well-being depend primarily upon the industrial background, the insistence that the benefit of modern industrial methods be more widely distributed has increased in like proportion. If I read the ideals of American democracy aright, we are committed in this country to an endeavor to secure universal well-being.

The benefits that have accrued to all classes of people in modern civilization are beyond question and are more apparent when comparison is made either with older forms of civilization, or even with existing handicraft nations. The general level of physical comfort and education as seen in modern nations is unquestionably higher than has ever before been attained. Nevertheless, no single class of people is satisfied with its position in the nation, and there is a deep feeling of unrest and discontent among those workers who actually produce the comforts of life. This is probably not new and undoubtedly has had its parallel in all older civilizations wherever large bodies of people dwelt closely together and where division of labor was at all a feature of industrial life. A multitude of reasons are advanced for this dissatisfaction and a multitude of remedies are offered for its mitigation, many of them having little or no bearing upon the real roots of the problem. It is obvious, however, from these suggested remedies that much if not most of these troubles have their roots in the industrial system under which we live—as might be expected, for industry is the very backbone of all existence. An examination of industrial laws preceding the present era and going back into remote antiquity indicates that modern industry has introduced few, if any, new problems. It has, however, accented and made more acute industrial problems that always arise where congregated industry and division of labor are factors in production.

Changes Wrought by Modern Methods Upon Industrial Life

Briefly, and without detail, the most important changes wrought by modern methods upon industrial life are as follows: The separation of agriculture and mechanic arts that began hundreds of years ago has been completed and widened. The agricultural worker now depends upon others for his tools of production. Within the mechanic-arts group the actual worker has been separated almost entirely from the ownership of the tools of industry. A complex system of transportation independent of either of these older fields of occupation has been developed. And, lastly, both in transportation and the mechanic arts, division of labor has been extended to a degree unheard of by our ancestors and made possible only by the use of modern tools of industry. The resulting complexity of human relations coupled with the vast increase in population has accented the time-old problem of "what is mine and what is thine?" to a point where many people despair of a solution and openly advocate a return to simpler methods and consequent simpler relations. The cry for justice, whatever that may be, is still abroad in the land, and we do not appear to have made much progress in attaining justice since the day when Plato described it as the essence of all good things.

Qualifications of the Engineer for Attacking the Problem of Effective Wealth Distribution

This charge that modern civilization is a failure or at least no improvement upon former civilizations, is, or should be, of peculiar

[1] Presidential Address at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers.

interest to the engineer, using this term in its widest sense to include all industrial workers who use the scientific method. For modern civilization is largely what he has made it, and the civilization of the future will be largely what he wishes it to be. It is too much of course to claim that the engineer, unaided, can solve these difficult problems, but it is undoubtedly true that if he will direct his energies to the problem of the distribution of wealth as earnestly as he has devoted them to its production he can make a contribution to industrial economics that will be exceedingly helpful. The engineer, and he alone, has a direct and personal knowledge of the great industrial machine that he has created. Until recently he has entrusted the operation of this machine to others who often knew little about its refined mechanism. It is high time that he took charge and operated this complicated mechanism himself.

There would seem to be little doubt but that modern productive methods on the farm and in the factory will eventually produce sufficient wealth to make universal well-being possible if our methods of distributing this wealth can be made properly effective to this end. Economists tell us that, as yet, we have not reached this point of production. It would seem, however, that even now if our energies were all bent more upon the production of necessities and less upon luxuries and pleasure-giving products, a great rise in the general level of well-being would occur. A superficial examination of every-day surroundings will convince any one of the tremendous amount of productive effort wasted now upon the things that profit us but little physically, mentally, or spiritually. To say the least, the prospect of a higher level of well-being viewed from the standpoint of necessary production is very hopeful.

Furthermore, it should be noted that the efforts of the engineer are no longer confined to the design and actual production of commodities. The principles of mass production that have so greatly reduced the cost of commodities he has now quite fully developed. The wide application of the principles of mass production has been made possible by mass financing, the work of the financier. The engineer, in turn, is now developing the principles of mass management, and his contributions to the philosophy of management are already noteworthy. I believe most business men would be surprised to know to what a large extent the methods of the engineer have invaded their chosen field, and there can be little doubt but that the near future will see the engineering type of manager a predominant figure in all industrial administration.

This adventure into a broader field has brought the engineer for the first time face to face with the greater problem of human relations in industry and the distribution of wealth. In times past he has given little or no thought to these problems, but has assumed that they lay outside of his field. This assumption is no longer true, and whether he wishes to consider these problems or not, they confront him in this new field of industrial management. He cannot avoid the issue.

It will be freely conceded that the preparation of the engineer for these new duties is far from adequate, and two of his shortcomings stand out conspicuously. The first is his lack of knowledge of the economic principles of industry and commerce. It is true, of course, that the field of abstract economics is still far from being an exact science and many of its theories are controversial. But that is no excuse for a lack of knowledge, on the part of the industrial manager, of this important and growing subject which aims to replace ignorance and empiricism with accurately reasoned results. Furthermore, every engineer is by nature an economist. The location of an industrial plant, the design of a great power house, the location of a railway are all problems in economics, and the tangible things with which economics is concerned are familiar objects to every engineer. This need in the equipment of the engineer is now fully recognized, and in a fair way to be remedied. All first-class engineering colleges now prescribe more or less economic study, and students of engineering recognize this study as a necessary part of their mental equipment.

Another important weakness in the mental processes of the engineer is his lack of knowledge of human nature and, worse still, his lack of sympathy with human problems. He is by nature a constructive individualist and usually impatient to obtain results; and, as a consequence, impatient of any obstruction, human or physical, that stands in the way of these results. And he is by nature a cave dweller given to introspection, unskilled in expressing his views verbally, and lacking usually in the companiable qualities that take strong hold upon subordinates. Of course there are many exceptions to these general criticisms, but in the main I believe they are true. This weakness, no doubt, is responsible for the failure of engineers as a class to take an interest in all civic matters and the reason why they have been, until very lately, a negligible factor in national affairs; though some of the present-day national problems are of especial interest to all men of this calling. But it would seem that this difficulty is, also, in a fair way to be overcome if one may judge by the great activity manifested lately by local and national engineering organizations in civic and national problems.

Over against these weaknesses of the engineer must be placed certain inherent qualities that strengthen his claim to industrial leadership. He is as a class essentially honest. His entire training and professional experience are such as to demand honesty of thought and purpose in all of his transactions. It is true, of course, that here also there are exceptions, but they are comparatively rare ones. Engineers as a class are honest, and if anything is needed today in management more than anything else it is this ancient virtue.

The engineer also often occupies a strategic position in industry which is of great importance in controversial matters. As the designer and planner of industrial enterprises he stands between capital and labor, and he is, not infrequently, better informed of the real difficulties at issue than are either sides of the controversy.

Furthermore, human progress must rest to a large extent upon a knowledge of the experiences of the race. This is true in all lines of human activity, and particularly true of a civilization that rests upon scientific achievement. The hope of the future lies largely in making accessible to all the great mass of accumulated experience that has come down to us. The engineer, of all men, has stood out preëminently in this respect as one who knows and uses classified knowledge to the fullest extent of his ability. The great leaders of the past had, for the most part, no conception of the importance of recorded experience. With few exceptions they took their knowledge and experience with them. The modern engineer has been the first to endeavor to reduce to written form the basic principles of industrial leadership, and his work in this field has already commanded worldwide attention.

And last, but most important, the engineer has command of the scientific method of attacking problems. With this he has practically solved the problem of production and is now rapidly rebuilding the field of administration. Is it unreasonable to suppose that he cannot make a great contribution to the problem of the distribution of wealth if he attacks this problem in the same whole-hearted manner that he has applied himself to these other fields of activity? There is indeed very good reason to believe that if he makes proper preparation he will bulk large in the industrial leadership of the future.

A New Form of Industrial Leadership Needed

All thinking men who know anything about industry agree that we are sadly in need of a new form of industrial leadership, but the source of this new leadership does not seem to be clear. And it should be noted that future industrial leadership will be closely associated with political leadership, so closely are the problems of industry linked with political administration. History gives us an idea of what has occurred in the past and gives us some basis from which we can draw conclusions as to the leadership of the future. The first form of national leadership was the military type, the rule of the strong man. This extreme form of leadership still prevails in some countries, though it is hoped that it has seen its day and will soon disappear from the earth. It was natural that the military form of government should be adopted in the first factories and large industrial enterprises. And this principle has certain inherent advantages that will undoubtedly prolong its use, though the modern tendency is to modify its more extreme features. The complexities of industry and the dependence that must now be placed upon expert advisers render any form of autocratic industrial government almost impossible.

In modern democracies military rule has been succeeded by what may be termed legal government. Today our social, political,

and industrial activities are governed by a very comprehensive code of legal regulations that rest upon precedent and upon the opinions of eminent jurists sometimes affirmed and reaffirmed many times. These legal restrictions are a valuable guide since they embody the experience of the race with conditions that have occurred. The lawyer has always rendered and is still rendering a great service to humanity in collecting public opinion and codifying it for our guidance; and for this reason the lawyer has always been prominent in public affairs as an interpreter of justice as prescribed by precedent and usage. The legal method and the legal mind, however, are for the most part backward looking in their processes. They aim to correct abuses as they arise in the body politic or in industrial life, and while the legal mind is of immense value to society, it cannot be said to have developed any philosophy of industrial life that holds out hope of a solution of these problems. An excellent illustration of our modified point of view as affecting the legal government of industry is to be found in our modern compensation laws. For many years all courts have held that a workman could secure compensation for injuries only if he could prove that he had not been guilty of negligence and that his fellow-workers had not been guilty of contributory negligence. Or in other words, the burden of proof was upon him to show that the blame lay upon the employer. This legal ruling had been confirmed repeatedly and it should be noted that, in general, the worker had to have recourse to law to secure compensation. Suddenly, almost, these old laws were swept from the statute books and the modern compensation acts passed which provide that workmen and their families shall not be made to suffer because of the dangers of industry. They practically affirm that accident compensation is a proper charge upon production and should be borne by the community interested and not by the unfortunate workman and his family who, usually, are not in a financial position to assume this load. This is clearly a step toward universal well-being and indicative, I believe, of other similar changes. There is, therefore, good reason to believe that the legal type of mind is not likely to produce the much needed new industrial leadership. In fact, it is more than likely that the legal regulations of the future will not rest so much as heretofore upon ancient usage, but will be greatly modified in their viewpoint by the new industrial conditions.

There remain for consideration two other types of mind from which a new industrial leadership may come, namely, the business or financial type, and the scientific type. The business type of mind with the aid and counsel of the legal and engineering fraternities has built up modern industry as we now see it. There can be little doubt as to the ability of this type of mind to plan and direct the larger aspects of industry along existing lines. One weakness of this type of mind lies in its apparent inability to appreciate or rather to acknowledge that a new industrial day has dawned in which industry is being viewed more and more as the support of human life and not as a means of producing private, corporate, or state profits. It is rather reluctant to admit the philosophy of universal well-being as defined in the foregoing. Whether it can be made to appreciate this view is an open question.

Another weakness of this type of mind is its lack of technical knowledge of modern industry. As industry becomes more and more complex the business man is compelled to depend more and more upon the engineer for advice and knowledge. It is this very phase of modern industry that is rapidly forcing the role of industrial manager upon the engineer. The truth of these statements is shown in considering complex industrial problems like the twelve-hour shift, which is partly at least a technical problem. The best report upon this subject that has as yet appeared is the report of the Committee appointed by the Federated American Engineering Societies. It is the best because it is based upon accurate technical knowledge of the industry and not upon speculative hearsay as most of these industrial reports are. The futility of any other kind of report is well illustrated in the Muscle Shoals controversy, which could be settled quickly and accurately by a properly chosen engineering commission. If the new industrial leadership comes, therefore, from the business world, the business type of mind, I believe, will have to be greatly modified.

Dean Inge, the noted London divine, reasoning along lines similar to the foregoing, comes to the conclusion that the only hope for new industrial leadership lies with the business type of mind on the ground that the scientific type of mind is somewhat visionary or theoretical and not practical enough for the solution of this great problem. With all respect to the learned dean, I would point out that workers in the field of science are of two well-defined types, and this distinction holds true probably for all fields of human activity. In science, as in philosophy, there are minds that may be described as *minds of the first order*. These are the minds that blaze the way by seeking out new truths whether of science, philosophy, religion, or what not. At no one time in the history of the world has there been a large number of such minds as compared to the total population, and the entire list of such great prophets, poets, philosophers, and scientists is insignificant when one considers the vast number of people that have lived on this globe. It is true that this type of mind is usually visionary and impractical, for which Heaven be praised! but upon it rests all hope of future progress. The true scientist who is interested only in discovering new truths or the man whose mind is even strongly drawn in this direction is usually not capable of directing the energies of others. But the engineering type of mind (which may be described as belonging to the class of *minds of the second order*) is interested in applied science and is for the most part eminently practical when brought into contact with practical problems. It is a mind capable of high development along business and financial lines, while yet retaining in its background the powerful scientific methods of attacking problems which have made modern industry possible. And this is the great contribution that the engineer can bring to this problem of universal well-being. The one great thing we are all seeking is justice; but there is no justice where there is no knowledge, and the engineer, again using this term in its widest sense, alone possesses an accurate and intimate knowledge of industry.

No one would presume to say that the engineer alone can solve the industrial riddle, but it is clear that he can make a very great contribution to the solution. But it becomes increasingly clear that hope of a solution rests with the two groups just discussed. The National Department of Education has for some time been advocating strongly that engineering students be taught more of the fundamentals of business and that young men preparing for the field of business and commerce be instructed in some of the outstanding features of engineering. And it may be that we shall yet develop a combination of these two fields that will produce the new type of industrial leader. But whether the new leadership comes from one field or the other, or from a combination of the two, the problem of universal well-being offers a challenge and a call to duty that the engineer may not refuse. The primary conditions and responsibility for universal well-being now rest upon his shoulders, and the engineer does not like to be concerned with a half-finished "job." There is good reason to believe he will do his share of work in attaining the ultimate results desired. Already there are significant signs that he has accepted this duty. The activities of city, state, and national engineering societies in all manner of civic problems in which they are competent to express an opinion need no rehearsal here. A few years ago it was unthinkable and unbelievable that an engineer should hold a high political office. Yet today we see with great satisfaction two engineers occupying gubernatorial chairs, one of them also an inventor of note, a Past-President of this Society and possessing a mind approaching at least that of the first order. More encouraging still we see an eminent engineer chosen, for the first time, to sit in the Presidential cabinet. These are pioneer adventures in a field that hitherto has been considered the exclusive territory of the lawyer and the politician, and their experiences are being watched with great interest by all thinking engineers. They are undoubtedly the vanguard of a larger invading army.

Whatever the result, we may be assured of one thing. Unless we can in some manner change our industrial system so that we can more nearly attain universal well-being and distribute the fruits of our industry more equitably, we have no reason for believing that our civilization shall endure, and its bones will full surely strew the shores of time along with those of the great civilizations that have preceded us. But if we can solve these problems, and I believe we can, there is hope that there may arise in America a civilization fairer than any that this war-weary world has yet seen, where universal well-being shall be a reality, and not a dream, and where liberty and justice shall prevail.

Making Goods and Making Money

By WESLEY C. MITCHELL,[1] NEW YORK, N. Y.

Engineers and economists, according to the author, have always had a common interest in production, but they have worked on different parts of the problem and have used dissimilar methods. Recently, however, the two sets of workers have come into closer touch, because economists have begun to use quantitative methods and engineers have begun to study the whole organization of the processes of production.

Quantitative analysis of production may run in terms of money, goods, or some index of welfare. As a community we are more interested in welfare than in goods, and more interested in goods than in money. But in practical affairs the business enterprise is forced to subordinate its interest in promoting welfare and in producing goods to the necessity of making money; for if it does not make money it will cease to produce.

The system of economic organization which presents this contradiction between our deeper and our more superficial interests seems, nevertheless, to promote the production of goods and material welfare more efficiently than any other plan which men have so far devised. It is a highly flexible system, offering free scope to the inventive genius of both engineers and economists.

Among the improvements needed at present are methods of stabilizing the monetary standard, controlling the business cycle, allowing production to be organized in units large enough to attain maximum industrial efficiency while safeguarding the community against high prices, etc. Engineers are equipped to make constructive contributions toward the solution of many of these problems.

BOTH engineering and economics have been concerned with the production of wealth since their beginings. But they approached the problem from such different angles and with such different aims that at the outset they scarcely came into touch. Adam Smith and James Watt were friends at the University of Glasgow when Smith was delivering the lectures which grew into the Wealth of Nations, and when Watt was making his experiments upon Newcomen's engine. Both of these Scotchmen had a plan for increasing the efficiency of production; but one plan centered in freedom for individual initiative, and the other in a separate condenser. It was not at all apparent at the time that this economist and this mechanical engineer could contribute to each other's work.

One hundred and sixty odd years have passed since Adam Smith and James Watt started their careers in Glasgow. In this interval the industrial revolution, which was getting under headway in the 1750's, has produced a new world. Looking backward, it is now clear that this new world is a joint product of engineering and economics. Adam Smith's ideas could not have influenced the reorganization of economic policy as they did without the development of steam power. James Watt's engine could not have run its conquering career without an opportunity for individual initiative. The mathematical instrument maker of the University of Glasgow and its professor of moral philosophy have been more intimate co-workers than either dreamed.

Meanwhile engineering and economics themselves have been growing. The engineer has begun to busy himself with other things than machine designing. He sees his problem as one which takes in all phases of the process of producing goods. He is interested not merely in his mechanical equipment but also in the choice and training of the personnel, in the planning and routing of work, in the purchasing and storing of materials, in the distributing agencies which handle the product, in the methods for winning markets, even in questions of financing. Thus the engineer has begun to attack many of the problems which concern the economist.

Although it must be admitted that the progress of the economist has been less rapid, he is to be credited with trying to practice the quantitative methods characteristic of engineering. Adam Smith had "no great faith in political arithmetic." His successors, blessed with better data and knowing more mathematics, are coming to have great faith in statistics. By the development of this technique they hope gradually to establish their science upon a quantitative basis.

This expansion of the engineer's problems and this improvement in the economist's methods are bringing the two sets of workers into closer touch. Today they are conscious of their common interests, as Adam Smith and James Watt were not. They wait no longer for a later generation to perceive that they are co-workers.

Fundamentally their common problem is still what it was when Smith was lecturing and Watt experimenting. The industrial revolution which was beginning then is continuing still. Every decade since 1750 has witnessed important advances in engineering and important changes in economic problems, if not in economic solutions. The need for further progress in the technical arts of production is not one whit abated by all the marvels of electricity and automatic machinery. Nor is the need for further progress in the arts of economic organization less pressing than it was in the generations of Adam Smith, Ricardo, or John Stuart Mill. The common task is to carry forward the industrial revolution through this generation—to carry it forward in such fashion as to make it yield our race still greater benefits.

It is not likely that economists can contribute to the further perfecting of machine design, though they may render help in problems of industrial organization. On the other hand, engineers no doubt can and will contribute greatly to the solution of economic problems. To those problems they bring a special type of training, an organized method of attack, which should enable them to see many things wanting or awry in the economists' conceptions. By constructive criticism they may make the economists' contribution more efficient, and in working with economists they may learn some things of advantage to themselves.

The Three Levels of Economic Analysis

All that I have said so far is exceedingly general in character. May I go on to matters somewhat more definite? My aim is to set our common problem of production in a perspective useful alike to engineers and economists.

The process of producing goods has been viewed in three ways. Subjectively it has been treated as a process of seeking to gratify wants. Industrially it is a process of making goods. From the business viewpoint it is a process of making money.

Corresponding to these three ways of viewing one and the same process of production, there are three levels of economic analysis—the level of satisfactions, the level of goods, and the level of prices.

Economic theory long cherished the ambitious design of penetrating to the satisfactions level of analysis. It sought to explain most economic phenomena in terms of a balancing of subjective sacrifices against subjective satisfactions. In so doing it became itself subjective. So long as it followed that tack it was not possible for economists to use quantitative methods. For, despite much searching, no satisfactory units have been found in which to reckon either men's sacrifices or their satisfactions. And without units, of course, one cannot cast up totals or strike averages. At best this level of analysis yields but a dubious explanation of why men behave in certain ways—"dubious" because modern psychologists have discarded for the most part the notion that our conduct is a calculated pursuit of satisfactions.

Gradually dropping this inefficient type of speculation, economists have recently begun to develop a more objective type of work—a descriptive analysis of economic behavior, as opposed to a subjective explanation of choices. It is this shift which enables them to use quantitative methods in their theoretical inquiries. We cannot measure sacrifices and satisfactions, but we can count goods and reckon in money. Within a limited range of problems we can also go behind commodities and prices to something more fundamental and yet susceptible of measurement—not sacrifices or satisfactions, but some objective index of physiological conditions or some objective record of behavior. For example, it is possible to investigate fatigue, to grade men by intelligence tests, to study the reaction of certain occupations upon health, and so on. It is true that

[1] Director of Research, National Bureau of Economic Research, Inc.

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these efforts to carry quantitative analysis into the realm of physiology and psychology are still in the pioneering stage, but does not the success already attained suffice at least to justify faith in future progress in this direction—progress to which not only engineers and economists but also physiologists and psychologists must contribute? For convenience of reference, let us say that this type of work runs on the welfare level of analysis.

The quantitative economist, then, and the engineer who attacks economic problems are concerned with money values, with goods, or with some objective index of welfare. As between these three levels of analysis there is no question but that the welfare level is the most significant and that the money level is the least significant. Indeed, money and goods get whatever significance they possess only in so far as they represent a contribution to welfare. We rate the goods level of analysis as more significant than the money level because a bushel of wheat has a more direct and unambiguous relation to welfare than has $1.25, which may be the price of wheat on some given day.

To illustrate the practical importance of these distinctions, let us refer to the national income. We should like to reckon this income in terms of common welfare, but we cannot conceive of welfare as a magnitude. So we do the next best thing and think of the national income as an aggregate of commodities and services obtained by the nation within a year. Such an aggregate we can conceive in bushels of wheat, tons of coal, board feet of lumber, ton-miles of transportation, months of schooling, and so on. When we come to measure this magnitude, however, we are forced to express the different classes of goods in terms of money values. That is, we make our computations on the most superficial level of analysis and state the national income in billions of dollars.

We are not forced, however, to stop short with so superficial a result, for we can work back again from money to goods. Thus, when our money estimates of the income of the American people show an increase from 33 billions in 1914 to 45 billions in 1916 we can analyze this nominal gain of 37 per cent into the part due to the rise of prices and the part due to the increase of physical output between a year of severe depression and a year of great activity. By applying appropriate index numbers of prices to the various sections of the data we can get revised estimates of the national income in "dollars of constant purchasing power." These revised figures come out as 33 billions in 1914 and 40.7 billions in 1916. That is, the estimate of the two-year gain in national income is cut down from 37 to 23 per cent.[1]

For most purposes this lower estimate of the increase in the national income in which the fluctuations of prices have been cancelled as accurately as may be, strikes us as more significant than the unrevised estimate. It is easy to increase the national income to any limit by monetary inflation—easy and harmful to welfare.

Where, then, do we stand in our efforts to treat economic problems by quantitative methods? What we seek to promote is welfare, but welfare we cannot measure except in certain details where objective indexes of physiological or psychological conditions are available. So we work on the assumption that an increase in commodities and services generally brings with it an increase of welfare. It is on that assumption that we seek to promote efficiency in producing goods. But we have to measure the progress of efficiency in money values whenever we are including goods of many different kinds. While we can afterward correct our figures for changes in the price level, they still remain in money terms—a hypothetical money of constant purchasing power. And the meaning of these monetary aggregates is exceedingly difficult to interpret except when we are comparing one such aggregate with another.

The Money Economy

The various levels of analysis in economic investigation are matters of profound and practical concern to the engineer as well as to the economist.

In considering the national income it is obvious, as previously stated, that money is important because it represents goods, and that goods in turn are important because they contribute to welfare. But in the process of production as now organized these relations are reversed in large measure. Production is carried on more and more by business enterprises, and business enterprises must make money if they are to keep going. The men in charge of a business enterprise may be filled with zeal for public service, but they must make enough to pay expenses and something over or they will have to find some other way of serving the public than running a business. The men in charge of another enterprise may be engineers interested primarily in perfecting their processes and products; but they must keep their passion for technical perfection within the limits set by money profit or they will be eliminated from the ranks of business managers.

It is no disparagement of business men to say that in business they subordinate the making of goods to the making of money. They are compelled to do so by the system of which we all are parts. If they fail to get their profits they cannot go on making goods. And it is to the interest of all of us that business men should get their profits, as every period of business depression proves. For when business promises losses instead of profits, production falls off and the national income is diminished, in extreme cases perhaps by 10 per cent.

But while it is silly to blame any one for this situation, it nevertheless bristles with economic contradictions. From the national viewpoint money making is a means toward making goods; from the individual viewpoint making goods is a means toward making money. From the national viewpoint the engineer is the central figure in production; in practice he takes orders from the business man. A community is well off in proportion to its efficiency in producing a current supply of the necessities, comforts, and amenities of life; an individual is well off in proportion to his efficiency in getting a money income.

This practical subordination of our common interest in making goods to our individual interest in making money produces grave consequences. But before enumerating them, it should be emphatically stated that the money economy is doubtless the best form of economic organization for promoting the common welfare which men have yet devised. This opinion is based on the fact that the money economy has developed out of simpler forms of economic organization in all the most progressive nations of the world, and that, broadly speaking, this development has been spontaneous. No one forced our forefathers in America to give up raising their own food, making their own clothing, and cutting their own fuel. They changed from the practice of making goods for their own families to the practice of making money incomes and buying goods made by others because they liked the results of the more elaborate plan better. In medieval times the king of England traveled around the realm with his court subsisting on the produce of the royal manors. When the king began to commute the labor services of his villeins and their dues in kind into money payments, the villeins shared with the king in the advantages of a better arrangement. So almost all the elaborate machinery of the money economy has grown up by slow degrees because men thought they got more goods or better goods when they worked for money than when they produced for themselves. The villeins have been converted into wage earners, the craft guilds have given way to the merchant and the factory, the weekly markets where neighbors met to barter have been superseded by retail shops, banking has evolved from small beginnings into an ubiquitous business, the joint stock company has become the dominant form of business organization, all because on the whole these changes recommended themselves on trial to large and growing sections of the population. Of course most of these changes were accompanied by grievous hardships to many individuals, but if the new organizations had not filled demands numerous enough to make them pay they could not have broken through "the cake of custom."

It must also be set down to the credit of the money economy that it is a marvelously flexible institution. It has been developed in a dozen ways undreamed of by the medieval money lender. Its capacity for further development and adaptation to human needs has no visible limits except the limits of man's capacity for invention. With that thought in mind let us consider some ways in which the money economy serves us ill, in the hope that the engineers and economists may invent practicable devices for bettering its operations.

[1] Income in the United States. By the Staff of the Bureau of Economic Research, vol. i, pp. 64 and 72. Harcourt, Brace and Company, 1921.

Some Developments Needed in the Money Economy

To begin with an obvious point, our dollar is not a stable unit. It is subject to continuous and wide variations in purchasing power, and these variations introduce uncertainty into business plans, cause undeserved losses to some and confer undeserved gains upon others. Various plans for stabilizing the dollar have been proposed—plans which merit critical study. But this whole topic is so familiar and its challenge to our inventive power so clear that this mere mention is sufficient.

Scarcely less obvious is the problem of controlling business cycles. Economic history shows that when any nation develops the money economy to such a point that a large part of its people get their livings by making and spending money incomes, its industry becomes subject to more or less regular alternations of feverish activity, financial crisis, and industrial depression. Of late years these business cycles have been the subject of quantitative investigation, so that our knowledge of the phenomena, while still far from complete, is yet sufficient to suggest various methods of exercising control over the cycle—methods such as the systematic scheduling of business operations with reference to anticipated changes in demand, the long-range planning of construction work, the launching of new products and increase of advertising when business is dull, more circumspect granting of credit in periods of activity, the improvement and wider use of business barometers, various schemes of unemployment insurance to reduce labor turnover and sustain the purchasing power of wage earners in periods of depression, and the like. Most of these plans emphasize the policy of "prevention rather than cure;" that is, they seek to diminish the wasteful excesses of booms as the best means of diminishing the severity of crises and depressions. All these plans are in the experimental stage. Engineers by virtue of their scientific training and their intimate relations with business men are likely to take an active share in testing these schemes and perfecting the best among them.

Another problem presented by the money economy is the clash between our desire for efficient production and our fear of being exploited by very large corporations. At present the work of production is systematically planned and controlled within the limits of each independent business enterprise. But we have no systematic plan for industry as a whole. Our industrial army is like a collection of military units of different sizes each efficiently led—squads under sergeants, companies under captains, regiments under colonels, a few brigades under generals—but an army without a general staff and without a general plan of campaign. However well the separate units are disciplined and led, there is loss of efficiency through lack of coöperation among the units. Under such circumstances, every increase in the size of the independent units extends the area within which careful organization exists and lessens the area in which no planning is possible. But as the companies combine into regiments and the regiments into brigades, we are afraid that the larger units will levy upon us a tribute which exceeds the savings from heightened efficiency. How, then, can we unite the efficiency of large-scale production with safety to the consumer? To that vexed issue of economic policy the organizing genius of the engineering profession may address itself with excellent results.

Other problems might be discussed—the possibility of cutting down the overhead which business needs impose upon industry, the possibility of raising the efficiency of Government service, the elimination of all methods of making money that are detrimental to public welfare, the advantages of investment in improving the personnel of industry as compared with the advantages of investment in plant, conflicts in interest arising from the immortality of nations and the short span of individual lives, what constitutes waste and how it may be minimized, the effect of changes in the standard of living upon production, the relations between the distribution of income and production of income—all matters of concern to engineers and economists alike. But enough has already been said to illustrate the main contentions, and illustration is all that is possible in treating so wide a topic in a brief paper.

To sum up, the industrial revolution has been marked by changes in economic organization as well as by changes in engineering technique. To keep this beneficent revolution going will require further changes of both types, economic and engineering. We should not be less alert to note the imperfections of economic organization than we are to note those of mechanical methods. In one field as in the other our best hope of constructive accomplishment lies in developing scientific analysis in quantitative terms.

How to make production for profit turn out a larger supply of useful goods under conditions more conducive to welfare is a problem that gives scope for the most diverse abilities and training. It is a problem that can be broken down into manageable parts which can be attacked by quantitative methods, and the advances made by one discoverer can be made the starting point of his successor.

The Human Problem in Industry[1]

By E. M. Herr,[2] East Pittsburgh, Pa.

That the human problem in industry is not a new thing is shown by the author's review of labor conditions in the Roman Empire, England, France, and this country, from ancient to modern times. With the increase in manufacturing and decrease in agriculture, however, new elements have been brought into the problem. A much smaller percentage of the population is now working and living conditions have greatly changed. The larger scale of industry places a greater degree of responsibility upon the manager, who must win the confidence of his employees and take every step known to scientific management to secure their coöperation, both for his own benefit and for theirs. According to Mr. Herr, shop representation, fair wages, security of employment, and means for education are among the demands of workers and merit the earnest consideration of all managers.

We are perhaps inclined to consider the present industrial problems as new and peculiar to this day and age and it is somewhat surprising to find how closely the labor problems and conditions of twenty-five hundred years ago approach those of today, in spite of a total change in background.

During a thousand years of ancient times, for the most part before the Christian era, self-supporting and self-regulating organizations of workmen existed, which were remarkably similar to the trade unions of today. They were publicly acknowledged and legislative enactments made to control them, notably the Roman laws of Numa Pompilius, who succeeded Romulus as emperor, and the Greek laws of Solon (about 700 B.C.). These laws, liberal for a time when the slave element entered so largely into industry and held up even today as models by labor advocates, were to the benefit of the state as well as the workers. (The tribune Tiberius Gracchus was their able supporter.) They were weakened however, under the reigns of successive tyrants. (Caesar, under the conspiracy laws of 58 B.C., broke up all the "unions" except those which were very ancient) and finally they were lost with the Christian massacres of Diocletian in the early part of the fourth century and the subsequent feudalism of the dark and middle ages.

The immediate cause of the destruction of these far-reaching labor organizations seems to have been the coveting of their wealth and power by the rulers of the day, together with their association with the persecuted Christians. Nevertheless the Christian movement early became a helpful factor in labor conditions, although it was first opposed by the unions because of its interference with the production of idols and other supplies for pagan temples.

The records of these workers' associations (Collegia) are fragmentary, but fully authenticated as including from century to

[1] In the preparation of this paper acknowledgment is made particularly to the authors quoted in the text, to Messrs. C. Osborne Ward (The Ancient Lowly) and W. L. Chenery (Industry and Human Welfare), and to Mr. Tracy Lyon for suggestions and valuable data, as well as for information made available by the National Industrial Conference Board.

[2] President, Westinghouse Elec. & Mfg. Co. Mem. Am.Soc.M.E.

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century most of the trades and crafts of the day. Numa formally recognized nine and Constantine, a thousand years later (337 A.D.), thirty-five, of which the following list may be of some interest: Architects, brass and copper smiths, blacksmiths, carpenters, decorators, doctors, founders, fullers (cloth), furriers, glaziers, goldbeaters and gilders, goldsmiths, ivory workers, joiners, looking-glass workers, lapidaries, masons, marble cutters, plasterers of various kinds, pearl and filigree workers, potters, painters, plumbers, pavers, sculptors, silversmiths, stonecutters, statuaries, veterinaries, wagon makers, workers in mosaic.

Even professions are included, but there are evidences of the existence of many other early organizations, notably of the armorers and iron workers, shoemakers, musicians, and gladiators.

Inscriptions found in the ruins of Pompeii show that the unions furnished members to be voted for as candidates to municipal offices, and what is more remarkable, these candidates then included women. As a historian puts it, "The inscription reads like some caucus slate of a New York ward Tammany club." The eight-hour law was also an issue of the times and every seventh day was observed as a day of rest. There were many strikes, usually called historically, when they attained sufficient proportions, "servile wars." The greatest and last of these was the uprising led by the gladiator Spartacus. Practically all ended disastrously, and it is authentically stated completely extinguished all hopes of the workers for the achievement of liberty by violent means.

And so the tide of the human element in industry has ebbed and flowed through the centuries, with its vital effect upon the welfare and happiness of all civilized peoples—through the feudal and medieval times with their greater or less industrial activity, when all mechanics and traders were organized into gilds possessing important legal powers and often exercising great political influence, to the time of the so-called English (industrial) revolution in 1760, which marked the beginning of the factory system and a departure from isolated craftsmanship under oppressive landlordism.

The vicissitudes were many. Under a Statute of Labor, issued in the fourteenth century at one of the times of plague in England, it was decreed by Edward III that thereafter labor should be given no greater wage than that received before the "Black Death," about 1350.

After the French Revolution all associations of either merchants, manufacturers, or laborers were forbidden.

Early Labor Problems in this Country

To come to our own country, at the beginning of the last century there were very few factories, and those then existing had only a small number of employees. We were a rural and agricultural people—as late as 1820 less then five per cent of the American people lived in cities with a population of 8000 and over. Today we are the greatest manufacturing nation in the world and over half of our population are city dwellers.

Farmers were of many classes—the richest, masters of principalities, and the pioneers, each with but a few acres of poor clearing. Manufacturing was a home industry, carried on chiefly by farmers and their wives, children, and servants, and by wandering mechanics. The artisan was sometimes a freeman but often an indentured or "redemptioner" servant. Many of these people were imported as late as 1835, their services being bought and sold.

The hours of labor in nearly all industry were from sunrise to sunset, even in the early New England textile mills, in which women and children did most of the work. It seemed entirely right in those times that little girls of ten should work fourteen hours daily, receiving about a cent and a half an hour.

Wages were certainly not high. In Massachusetts, for instance, from 1800 to 1815 laborers received from 35 to 75 cents a day; carpenters and blacksmiths about $1.00; millwrights, machinists, painters, coopers and foundrymen about $1.13; a mason as much as $1.66; tailors and shoemakers about $6.00 a week, and women employed as domestic servants their board and 50 cents a week.

In such a world the foundations of modern industry in America were laid. From the beginning of the 19th century the factory system steadily grew with the accompanying human struggles. About 1825 occurred the first strike for a ten-hour day. "Sweatshop" methods had then begun, but there was as yet no method of reducing the labor cost of production by the use of labor-saving machinery, outside of the textile industry.

Local trade unions sprang up more or less intermittently early in the century, principally in the shoemakers' and printers' trades, both for mutual benefit and insurance, and for the reduction of working hours and the increase of wages, but it was not until the fifties that national organizations began to take effective form. These were pretty well shattered by the depression preceding the Civil War and did not really come into being until the seventies and eighties.

With the constant growth of the factory system and the continued development of machinery, the value of all manufactured product in the United States, estimated at about $170,000,000 in 1812, increased to more than $60,000,000,000 in 1919, or approximately three hundred and sixty fold, while the population had increased sixteen fold.

In this comparison the consideration of relative commodity prices would reduce the output of 1919 by perhaps one-third. Prices were very high immediately succeeding the World War and accurate comparable figures of the early period are not available.

The Colonial manufacturer was the mechanic or artisan who had gathered about him a few journeymen and apprentices.

Increase in Size of Manufacturing Plants

Reference has been made to the effect on the human problem in industry of the great increase in the size of manufacturing establishments, as with this increase personal contact between employer and employed necessarily becomes more difficult.

Judging from the trend of public sentiment, it might be assumed that the factory system is practically dominated by the so-called interests or trusts, but as shown by the United States census of 1920, by far the greater number of manufacturing establishments even now are small—over eighty per cent with twenty or less hands and nearly ninety-five per cent with less than one hundred—although it is true that nearly forty per cent of the wage earners are concentrated in what might be called large establishments, and upward of seventy per cent of those having above one hundred employees. A summary of the figures is as follows:

Distribution of Establishments		Number of Wage Earners per Establishment	Distribution of Wage Earners	
Number	Per cent		Number	Per cent
235,881	81.3	20 or less	943,586	10.3
37,795	13.0	21 to 100	1,725,683	18.9
13,661	4.7	101 to 500	2,831,456	31.2
2,768	1.0	Over 500	3,595,647	39.6
290,105	100.0		9,096,372	100.0

It may be mentioned that according to a recent authority the number of existing monopolistic "trusts"—that is, combinations controlling in the neighborhood of three-quarters of the national supply of their respective outputs—probably does not exceed one hundred, and practically all of these came into being between 1887 and 1903, nearly twenty years ago.

Under our liberal incorporation laws, perhaps too liberal in their lack of uniformity, corporate management is increasing. The proportionate number of employees and the value of the product of manufacturing corporations, as distinct from industries managed by individuals or partners, comprising nearly seventy-five per cent of the whole fifteen years ago, has increased to nearly ninety per cent.

Racial Composition of Workers

An important element in the human problem in industry of today is the racial composition of the workers. According to a report of the United States Immigration Commission on conditions before the war, the distribution of industrial workers at that time was about as follows: Native-born Americans of native father (5 per cent of these colored), 25 per cent; native-born Americans of foreign father, 17 per cent; foreign born, 58 per cent.

It is interesting to note that the first-mentioned class, or more purely American, was employed most extensively in railway transportation, the manufacture of cars and locomotives, electric supplies, firearms, knit goods, gloves, collars, shoes, cigars, tobacco, etc.

With industry dependent to such a large extent upon foreign-

born workers, the recent immigration laws threaten, for lack of "common" labor, the return to and maintenance of normal production, and it is to be hoped that these laws will be made reasonably liberal and that restrictions will be based on fitness instead of as at present without regard to the immigrant's character or qualification to become an American citizen.

Decrease in Percentage of Workers

As has been pointed out, in the early days of this country almost everyone was an industrial producer, including the housewife and children above the age of seven. It is rather surprising to find that, according to the United States Census of 1920, about forty per cent of the inhabitants of the United States support the entire population, directly or indirectly, according to the following distribution:

	Per cent	
Persons Engaged in Gainful Occupations:		
Manufacturing and mechanical industries (including building trades)	12.1	
Agriculture	10.3	
Trade and clerical	7.0	
Transportation	3.0	
Mining	1.0	
Public and professional	2.8	
Domestic and personal	3.1	39.3
Not Engaged in Gainful Occupations:		
Over ten years of age	38.9	
Under ten years of age	21.8	60.7
		100.0

Although our Government has from its inception fostered manufacturing industry, largely by tariffs and patent laws, there has been since the time of Alexander Hamilton a public feeling and belief that agriculture was the backbone of the nation and manufacturing a supplementary source of wealth. To this belief may be attributed no small part of public indifference to the ills of working conditions.

The Human Problem in Industry

Let us now turn our attention more directly to this problem in an endeavor to ascertain at least some of the directions toward which its solution trends.

There is a human problem in industry because human nature is as we find it and as it always has been. This problem, as we have seen, is as old as humanity and will in all probability continue throughout the ages to come. It has varied and will continue to vary in intensity and in character. A study of the past and present conditions, however, gives promise of a continued and steady improvement in the relations of those who make up this problem. How, then, can this improvement in industrial relations be best continued?

The principal new thing about the human problem in industry is that industry is now conducted on a large scale—larger than ever known before—and that the problem has been intensified not only by factory employment and all that goes with it, but by the greatly increased size of manufacturing establishments, by the concentration of population in cities having a large foreign element of often radical tendencies, and by the insecurity of employment, in which business cycles play a large part. Furthermore, a very large number of people are now entirely dependent upon industrial operations, as those employed in manufacturing in early days were not.

These are concrete things and all conspire to produce conditions which cause what is perhaps the greatest problem in the industrial relations of today, that is, the underlying labor unrest and distrust, born of fear and misunderstanding—fear of coercion, unemployment and sickness—and a lack of mutual confidence as between employer and employed. There is more liberty and consideration for the workers than has ever been known before, and with it has come to the workers the greater vision of what they believe should belong to them in welfare and happiness. The social responsibility of management is being emphasized as never before.

Of first importance is the responsibility of management in its broadest sense. The awakened worker of today, more sensitive than his predecessors, intelligent, critical and perhaps irritable, must be convinced of the ability of management as well as its good faith, and in extreme cases even of the necessity of its being. It is said that democracy without management reverts to despotism on the mere ground of its inefficiency, and that the fundamental error in the recent Russian failure to provide for its people was confiscation of the factories and the expulsion of the managers, with the resultant breakdown of discipline and credit, on a false theory that labor alone creates wealth, whereas management, with credit and good faith, is of the first importance in the process of production.

"Effort in itself" says King in Industry and Humanity, "is of little value; it is only effort intelligently directed that counts." The Bolshevik dictators are reported to have been compelled, as a means of existence, to resort to despotism in the name of labor in the prohibition of strikes enforced by the army, to proposals of "scientific management" at any expense, and to offers of high salaries to the old managers if they would return.

It is the duty and responsibility of the management of today to prove its "reason for being" and that the collective result of the combined efforts for managers and workers is a fine and great thing. If they can feel that this is the case, most men will toil cheerfully as subordinates.

It is management's problem to obtain the confidence of their employees, to give them every reason to believe and convince them by their experience that their treatment is fair and honest and without "bluff." Since men are naturally distrustful it takes time to establish such confidence, and they will discover very quickly if the "boss" is not square. It must be established as between man and man for the good of humanity as well as the individual that labor and management are not foes, but that their interests are in every practical sense identical.

The personnel department is now often the means of establishing, that contact with employees which is so essential, governing employment, education and welfare, as well as shop representation. Its intelligent extension still has far to go and it is regrettable that some companies have seen fit to curtail this activity in times of depression when they and their men need it most.

These relations should not be handled and directed by the personnel department alone. The active heads and real managers are the ones on whom this responsibility must rest and who must handle it with their employees, not occasionally nor spasmodically but regularly and continuously, for work of this kind requires a great deal of time and patience. This effort on their part will gain the confidence of the employees and instil a spirit of coöperation throughout the organization, and it must be exerted on those directly in charge of the daily work of production. Anything less than this is futile and doomed to failure.

Boards of directors must keep in mind this relation and work with the officers in determining policies which the managers can carry out without destroying valuable relations established only after long and patient work and almost impossible to renew.

Shop-Representation Plans

One very large organization cites good practical results of some five years' experience with a plan of joint representation of men and management "along simple, plain lines that can be lived up to." They find that if the men are free to make suggestions to the management they will not ask an outsider to do it for them, and that most questions are settled by local boards. They find that workmen are anxious to learn if given a chance, and encourage the study in factory schools of the work of other departments. This broadens their perspective and increases their interest in their own work. They want to see every worker a capitalist, with an interest in the company's stock or with a savings account. In view of the justice and importance of steady work, their personnel department has special instructions to obtain advance notice of necessary layoffs so as to provide other jobs, if possible—this for the benefit of the company as well as of the men.

It is credibly stated that at present there are in the United States more than 300,000 employees working under shop-representation plans created to give them a voice in the conduct of the shops in which they work, and that in by far the larger number of cases considerable progress has been made in establishing the most cordial relations between management and employees.

Reference has been made to fears on the part of labor, such as fears of layoff or discharge, of arbitrary exactions and reductions in wages, of unfair discipline, of ill-health, and until unnecessary fears of this sort can be removed by a better understanding and

assurance, labor is obviously incapable of devoting its best energy to production. It is consuming time in organization against ills that are feared and thereby losing its just and full reward for effort in wages and opportunity for wider employment, which would be provided by greater public confidence in the investment in industry, as well as the elimination of the enormous waste in the joint effort which such mutual fears entail.

As put by W. L. Mackenzie King:

> Consideration of how best to eliminate fears respecting the distribution of output touches the crux of the industrial problem. How is the just share of each party to industry to be determined? And how is each to be guaranteed its right to share progressively in increasing productivity, and be held also to the corresponding obligation to see losses proportionately shared?

Wages

The last-mentioned obligation is often overlooked. Nominal wages have increased enormously; according to the United States Bureau of Labor Statistics, the average hourly rate increased seven fold from 1840 to the peak in 1920, and it is safe to assert that real wages have also augmented despite the high cost of living and the fact that in the early days of industry few workers depended entirely upon their wage but were "found" many things which must now be purchased; also the employment of young children was considered proper and the mother bore an undue part in family support, both practices which are now recognized as wrong, although not as yet adequately provided against by law.

Manufacturers naturally wish to see their employees receive a wage, with reasonable working hours, which will support them in comfort. This, of course, is only possible when economic conditions will permit, as wages are not and cannot be based on the cost of living. If this condition is to obtain, the employee must live in accordance with his income and responsibilities and exercise frugality and care in his expenditures. Unless this is done, the real interest of the employer and employee will not be conserved because wages would be lifted to the point of throttling the industry. The employer must also see to it that restrictive regulations, which weaken organization and curtail output, are not employed, either generally or for the benefit of any group or class of employees. Dr. W. I. King, in Wealth and Income of the People of the United States, states this principle very clearly as follows:

> The grim fact remains that the quantity of goods turned out absolutely limits the income of labor and that no reform will bring universal prosperity which is not based fundamentally upon increasing the national income.

Scientific Management

Scientific management—which is in fact little more than getting rid of confusion and perfecting adjustments, or in other words, good management—has entered largely in recent years into the human problem in industry. Its use may be abused, of course, but as helping to avoid undue strain on the part of the worker, under modern mechanical methods, and waste of time and materials in many directions, it should be of benefit to all concerned in industry as well as to the community. It should be a part of such management to remove the cause of any hostility to the broadest application of scientific knowledge of the conditions of maximum labor efficiency, to the gain of all parties to production. The scientific management which dealt in the earlier stage with individual output in an engineering way must now deal with men collectively and develop that scientific breadth of imagination and application which is becoming a vital necessity for the welfare of a modern civilized community.

In the introduction to the last edition of Trade Unionism and Labor Problems, Professor Commons says:

> Fifteen years ago insurance and unemployment were placed last, now they are placed first in this book.

Further on he says:

> The psychology of labor, both in good and hard times, is fundamentally the psychology of a class of people whose life is insecure, who are subject to rough methods of discipline. We cannot understand the problem of dealing with labor unless we understand that fundamental fact of insecurity of employment.

The accident-compensation law has accomplished the first little step toward giving security to the job. It has shown that the only way to establish safety and security is by making it financially profitable to do so. And so shall we make it financially profitable to business to eliminate to a large extent the wage loss due to unemployment on account of sickness, on account of changes in seasons, and on account of fluctuations in business. Labor can never accomplish this result. The only possible accomplishment of it will come when the employer arranges to cover unemployment from sickness by some adequate form of insurance, to the expense of which the employee will contribute, indemnifying the employee against loss of employment from this cause (accident is now covered by our compensation law), and to lessen unemployment on account of the fluctuation in production because of changes in seasonal demand by the proper use of stocks of finished product so as to smooth out these fluctuations and also those due to abnormal variations in business activity. The latter are much more difficult to provide against as they are irregular and often of large magnitude. When very great they cannot be entirely smoothed out but can always be lessened and are a real problem worthy of the effort of any manager.

Not only do increased security and continuity of employment greatly lessen the human problem in industry but on account of lessened labor turnover and uniformity of production they also reduce the cost of the product.

Many progressive industrial organizations have gone far beyond the requirements of the accident compensation laws and the safety of the worker, incurring large expense in providing liberally for free life insurance for their employees, advantageous savings and loan opportunities, housing, service pensions, and education. This education provides employees, at nominal or no expense, with almost every curriculum desired, from the teaching of English to foreigners to a vocational or technical course, the education of trades apprentices and the training of college men for service in the manufacturing, engineering and sales departments.

Education of Workers

There are other phases of helpful education which might well be prompted by the conditions of modern industry. One of these is in pointing out how to make repetitive work, in itself monotonous, interesting. A knowledge of the "why" of their product and the use of it and of related products of other departments has been found to materially broaden the operator's perspective. Then, too, workers can be encouraged to exercise their ingenuity in devising means to lighten and quicken their work and thereby incidentally increase their earnings. With shorter working hours there arises the question of what to do with idle time. Any one who investigates the use to which the average employee devotes his leisure undoubtedly will be convinced that such employee would be much better physically, mentally, and morally if he had less idle time, for it is generally used in loafing or in amusements which consume a material part of his earnings without corresponding benefits.

The question is often raised, "Is there not a great source of satisfaction in attainment?" Work well done and with a knowledge of progress is a source of enjoyment and with many takes the place of the recreation others find necessary to their happiness. Education of both sexes in ways in which to use leisure time profitably yet pleasantly is needed. The tendency toward shorter working hours makes the training of the young to use their leisure profitably more and more important. They should be taught thrift, for a thrifty person will not uselessly waste his leisure time.

The human problem in industry cannot but be largely affected by example. H. G. Wells, in some articles written about ten years ago on the labor unrest in England, which are unfortunately quite applicable to our conditions of today, speaks of the disturbing influence of "the obvious devotion of a large and growing proportion of the time and energy of the owning classes to pleasure and excitement" and the way in which this spectacle of amusement and adventure is being brought before the eyes and into the imagination of the working man. "We have, in fact," he says, "to pull ourselves together and make an end to all this slack extravagant living. I believe that in making labor a part of every one's life and the whole of nobody's life lies the ultimate solution of these industrial difficulties."

The human problem in industry, as has been pointed out, is very complex and can never be entirely solved. We will do a great

and valuable service to humanity if we can measurably improve the feeling of confidence of the employee in the employer and gain his hearty coöperation. To obtain this much, however, in addition to our educational work in its broadest sense, we must always and fundamentally be absolutely honest in our dealings, not only honest in our actions but also in our thoughts and intentions. Unpleasant facts necessary to be told to employees should be given them as honestly as the others and very promptly so as to give them all possible time to adjust themselves to difficult or distressing conditions.

Finally, is it not clear that at least one direction of the solution of this human problem in industry is along educational lines? First, education of ourselves, the employers, to a more general understanding of the spiritual, personal, economic, and physical relations involved; and second, education to encourage and aid in every proper way the general and vocational training of the employees in thrift, especially the younger boys and girls, but also the mature but still impressionable group of young men and women who are keen to learn how their position in the workaday world can be improved. Example in this effort to educate and train the employee is especially effective. Such educational effort should establish confidence and encourage coöperation. It should also be directed so as to develop individuality in each workman and woman. The sense of individual progress and freedom was the controlling motive with the founders of this great country. By keeping this characteristic strong in our young people we will perpetuate, strengthen, and develop the true American spirit in our land.

Let us therefore substitute the rule of reason and intelligence for force and so endeavor to restore in America the freedom of the individual, be he employer or employee,—"that freedom which enables the young man to look into the future with confidence, knowing that the only limitations to his achievements are the boundaries of his intellect and the measure of his energy."

Discussion at Engineering and Economics Session

At this session of the A.S.M.E. Annual Meeting, held in the auditorium at 8 p.m. on Wednesday, December 6, under the joint auspices of the Management Division of the A.S.M.E. and the American Economic Association, two papers were presented: namely, Making Goods and Making Money, by Wesley C. Mitchell, Director of Research, National Bureau of Economic Research, Inc.; and The Human Problem in Industry, by E. M. Herr, President, Westinghouse Electric and Manufacturing Company. The texts of these papers appear on the pages immediately preceding.

President Kimball, in calling the meeting to order, said that the occasion was undoubtedly unique in the history of professional organizations. The American Society of Mechanical Engineers had long been interested in many joint activities having to do with a wide range of affairs, engineering, scientific, humanistic, but so far as he was aware, this was the first time that engineers and economists had gotten together in joint session to see what one might learn from the other.

Later, in opening the discussion, President Kimball said that Dr. Mitchell had brought forward probably the most important problem that engineers have before them today, namely, how are they to obtain this knowledge of economics to which he has referred? Colleges of engineering began some years ago in an endeavor to have all students taught the elements of economics, and the largest institutions now require a certain amount of instruction in that subject. It is not an easy thing to secure the attention of the students, however, for to them it seems a strange subject. That is natural, because we all are afraid of the things we do not understand, and just as the engineer was afraid of economics, others are afraid of engineering.

We are in need of some common basis, some common denominator of thought, and one of the first changes which has to be brought about is the simplification of the language which the engineers and economists speak. When we get to the point that we can write the elementary principles of engineering and economics so that he who runs may read, there will be some hope of a mutual understanding.

Discussion by Prof. H. R. Seager[1]

I find myself in such full agreement with both Dr. Mitchell and Mr. Herr that instead of criticising I will ask you to consider another application of the clarifying distinction Dr. Mitchell made between the money, the goods, and the welfare aspects of our economic relations. He called his paper Making Goods and Making Money. Perhaps the best title for my remarks would be Making Men and Making Goods, for I wish to direct attention to a problem which has its money aspect and its goods aspect, but which can be solved satisfactorily only by reference to its welfare aspect. It is in weighing against each other gains that can be stated in terms of goods and gains that can be stated only in terms of welfare that economists and engineers have their most difficult task. Or perhaps I should say that it is in connection with the goods plane that engineers should be able to render their greatest service to economists, and in connection with the welfare plane that economists should be able to repay some of their debt to engineers. But, as Professor Mitchell pointed out in dealing with welfare problems, we lack the exact means of measurement which we have when considering monetary or goods problems. Argument must take the place of demonstration, and in the end equally intelligent men must often agree to disagree.

Let me illustrate by reference to a practical problem that is sure to receive an increasing amount of attention during the coming year, the problem of the restrictions that should be imposed upon immigration. If this problem were to be decided as a problem merely of making goods, we should all have to agree that the present restrictions, the virtual exclusion of Chinese and Japanese immigrants and the limiting of immigrants from other countries within a year to three per cent of the number from each country who were shown to be here by the census of 1910, are obstructing the material progress of the country and should be repealed.

As a result of the war that steady stream of immigrants, averaging a million a year from 1910 to 1914, which used to recruit our industries, was largely checked. The net gain in our foreign-born population from 1910 to 1920 was thus only 3 per cent as contrasted with 31 per cent in the preceding decade, and from constituting 16 per cent of our total in 1910 they had come to constitute only 14 per cent in 1920. In 1921 wholesale misery in Europe was balanced by widespread depression and unemployment in this country. There was danger that immigrants would seek our shores again in large numbers when our industries were unable to afford employment even to our own citizens. It was to meet this situation that Congress in May, 1921, passed the per centum limit act which in May of this year was extended for another twelve months.

Our industrial situation is now quite different. In all parts of the country our industries have revived and in place of unemployment we have at present a real scarcity of many types of workers. It happens that this scarcity is most acute in the case of unskilled laborers, the very type that predominates among our European immigrants.

The arguments for letting down the bars and allowing the hundreds of thousands of laborers we could undoubtedly employ to enter are, from a business point of view, very strong. By maintaining or even advancing our standards of admission as regards physical fitness we could undoubtedly secure in large numbers just the type of sturdy and docile workers for which our industries are now clamoring. Accustomed to much lower wages than prevail in this country, these men would accept with enthusiasm current rates of pay, and the trend of wages upward which is proving embarrassing to our reviving iron and steel, copper mining, and other industries would be checked. Moreover, immigrant labor from a national point of view is always cheap labor. Other countries have borne the cost of rearing immigrants during the unproductive years of childhood, and in admitting them in early manhood we reap the full benefit of this investment without having to contribute anything to it.

There can be no question, then, that a return to our more liberal

[1] Professor of Political Economy, Columbia University.

prewar immigration policy would enable us to increase substantially our output of goods, and of this large output a goodly share over the wages we should have to pay for immigrant labor would remain as profits to employers and investors and constitute a net addition to our national wealth.

Notwithstanding these certain material advantages, economists very generally oppose a return to our former liberal immigration law and for reasons with which we are all familiar.

In this matter there is much more at stake than our national wealth. It goes to the very heart of our national welfare. Although most of us did not realize it, the admission of an average of a million immigrants a year before the war came dangerously near to wrecking our country, politically, socially, and economically. In saying this I do not intend to assert that our native Americans are demonstrably superior to the immigrants who come to our shores even from Southeastern Europe. What is certain is that they are more familiar with our institutions, more generally convinced that these should be maintained, and better trained in their operation.

When we admit an immigrant we admit not merely another pair of hands for our industries, but another potential citizen to strengthen or weaken our vital national institutions. Under the present 3 per cent restriction 357,803 immigrants may enter the country during the current year. The number who will actually come in will be substantially less because the countries of northern Europe will not send us the quotas to which they are entitled and which we should gladly welcome, while the countries of Southeastern Europe will be permitted to send us only a tithe of those who eagerly desire to come. But though the number may not exceed 250,000, or a quarter of the prewar average, economists generally feel that that will be quite as many as we can wisely undertake to assimilate in these troublous times.

The truth is that we have on our hands a highly difficult problem in trying to educate our present one hundred and eighteen million people to a better understanding of some of the elementary facts of economics and government, and cannot afford to complicate this task by admitting too many whose ideas and standards are already fixed. According to a recent writer,[1] the maximum population which the continent of the United States can support is about 200,000,000 and to maintain even this number it will be necessary to import nearly if not quite one-half of our food supply from abroad. Moreover it will take less than 200 years for us to multiply to this extent even if we make no net additions to our foreign-born population in this period. These estimates may be exaggerated, but they emphasize forcibly the truth that our population will multiply quite rapidly enough without any immigration, and that our great concern henceforth must be over the quality rather than the quantity of our people.

According to one of our leading biologists,[2] owing partly "to the great influx of foreigners of low mental capacity," but even more to the relatively larger families of our less intelligent natives, "our average intelligence has probably been declining for the past twenty-five years at least." Just what this means was brought out in startling fashion by the results of the intelligence tests applied to the 1,700,000-odd drafted men during the war. According to the same writer these tests indicated that 45,000,000, or nearly half of our population, "will never develop mental capacity beyond the stage represented by a normal twelve-year-old child, and that only thirteen and a half millions will ever show superior intelligence."

Clearly we need a respite from adding further to the number of our population of the routine manual laboring type and should concentrate all the time and attention we can spare upon means by which we can prevent the 45,000,000 at the bottom of the intelligence scale from further multiplying while we increase the thirteen and a half million of superior intelligence until they become the predominant American type. Unless we thus deliberately subordinate our goods or wealth interests to our national-welfare interests the rights to life, liberty, and the pursuit of happinesss, which we still consider our most precious national inheritance, will lose their only certain sanction, a representative government responsive to an intelligent as well as independent citizenship.

[1] R. Pearl, Proceedings National Academy of Sciences, June, 1920.
[2] E. G. Conklin, The Direction of Human Evolution, p. 104.

DISCUSSION BY ERNEST F. DUBRUL[1]

In the first part of his paper, Dr. Mitchell comments that engineer and economist today are conscious of their common interests and perceive that they are co-workers. This comment is of course evidence that they have not been collaborating in the past to any great extent. In his presidential address to the American Economic Association last year, Dr. Hollander brought out the costliness of this lack of contact during the war, how the neglect of economics led to misguided policies in labor adjustment, price fixing, revenue provision, and banking administration. He showed that on the one hand economists failed to mobilize as other scientists did, and on the other there was no instinctive recourse to the economist on the part of public authority, as there was to other scientists.

It is truly regrettable that instead of economics being recognized as the human, humane science that it really is, instead of it forming a valuable part of the business world's working knowledge, we find it considered, and for the most part still taught, as some form of esoteric mental gymnastics for college students. It is high time that both the economist and business man take effective steps to bring economics into its own proper place.

Dr. Mitchell has said that "engineers no doubt can and will contribute greatly to the solution of economic problems, to which they bring a special type of training which should enable them to see many things wanting or awry in the economist's conceptions. By constructive criticism they may make the economist's contribution more effective and in working with economists they may learn some things of advantage to themselves." As one working with both elements I can add a hearty "Amen" to that statement. More than that, I would appeal to both elements to give sympathetic attention to what each has to offer in the way of constructive criticism.

I do not lay all the blame for lack of collaboration on the economists; the greater part rests properly on the shoulders of the business men and the managing engineers. Measuring the great economic progress of the world, we may jump to the conclusion that economics cannot be of much value since so few of the business men who brought about this progress know anything of economic theory. But measuring the human element we find that very few people in all the world ever undertake a business enterprise, and of those few who do, a very large proportion fail, and the failure are not all small ones by any means.

It is not illogical to presume that more knowledge of economics would make far more successful business structures, just as more knowledge of other sciences and their better application has made more successful mechanical structures. We no longer leave the design of costly and important mechanisms to men who disclaim and even disdain the worth of education in physics and mathematics, because we have found the percentage of failures to be less when we had those mechanisms designed by men trained in theory as well as practice. The engineer's function is to consciously coördinate practice and theory, and to do this he must have a knowledge of both.

In puzzling out reasons for the lack of contact between business and economics, I have concluded that it is because, in sales terms, business has not been "sold on economics." To the suggestion that economic science deserved being "sold" to business, an economist of the academic type gave me the shocked response: "Why, that would commercialize the science, and destroy its cultural value in our course." To my unacademic mind economics, like engineering, is essentially commercial. I think it could be made decidedly more cultural than it is now if more teachers taught it as a science of living humans instead of as though it concerned on economic specimen preserved in academic embalming fluid. Far from shrinking at the fling of commercialism, I am for selling economics to the business world, as we have sold chemistry, physics, mathematics, geology, and other organized divisions of human knowledge.

We business men have learned that to procure consumer acceptance for our goods we must hunt out, run down, coax, stimulate, and manipulate our demand. We have learned that such acceptance depends—

1 On the sales effort made, its attractiveness and effectiveness

[1] General manager, National Machine Tool Builders' Assn.; Mem. Am. Economic Assn.; Assoc-Mem. Am.Soc.M.E.

2 On the service we give our customers to keep them sold after we have reached them
3 On the effective utility of the goods we have to sell
4 And least, perhaps, on the price we ask.

In analyzing a sale we business men have also learned the four steps through which we must lead our customer's mind to accomplish the desired transfer of our goods to him and his money to us. These are: attracting attention, arousing interest, creating desire, and inducing action.

Wherein have purveyors of economic science failed in these? As to attracting attention, many of the best of our economists seem to prefer academic retirement—and ease—to the hard work necessary to popularize the science. They may have a mistaken notion that it is unscientific or unprofessional, or undignified to make a science so popular as to promote effectively its application to every-day life. If any science ought to be and can be made popular it is economics, the one that deals with getting our living.

The opportunity of arousing interest in economics is ever present. Business men are always interested in the question, "How is business?" Their wives often talk about the domestic labor supply. Workingmen think a lot about jobs and wages; politicians and citizens think about taxes, and the gathering and spending thereof. Even professors worry at times about the cost of living and whether the latest drive for endowments will be successful enough to increase their own salaries. It would seem very noble to do everything possible to direct this general interest toward constructive rather than destructive action.

Economists have evidently not created much desire, much appetite, for economics; and Dr. Hollander gives testimony that in the great war crisis they did not induce good economic action. Perhaps it is because they have not presented their wares in an attractive, appetizing manner. Dealt out as dry, unpalatable brain fodder, economics cannot have as strong an appeal as if served in the form of a sparkling beverage to quench a human thirst for knowledge. Because it has been subjectively treated, as Dr. Mitchell has said, it seems to me that the quality of the wares has been defective. It is a fatal defect in economics to assume as true for the whole what business experience proves to be true only for a part, or to assume as true at all times things that are actually true only a part of the time.

Men of course think only as they know, and of course they write as they think. Few writers of economic texts have had business experience. They mostly have but limited knowledge of fabrication and exchange. Their personal exchange experience is limited to purchasing the most evanescent of all goods—food, clothing, shelter. So they subjectively formulate laws of supply and demand from that consumer angle, and apply that formulation to a mere abstraction, the economic man, buying and selling goods and services in a perfect economic market. But this method takes no account of the human element swayed by caprice and favoritism, and hampered by ignorance and folly. According to this theory the seller always extracts the last penny of profit from every sale. It must be the engineer's function to constructively criticize such a formulation of theory.

Take the absurd expressions, "normal price," "normal wage," "normal profit," "normal business." The "normal price" notion leads people to chasing price-fixing rainbows, meanwhile baying the word "profiteer." The "normal wage" notion leads unions to attempt to level up wages regardless of efficiency. The "normal profit" notion leads to envy of superior capacity that can make two healthy blades of grass grow where most competitors can only get one sickly sprout. The silly "normal business" notion leads men to run their business craft aground when the tide of demand goes out. That fallacy of a "normal business" has destroyed much wealth and wasted much human effort. Men have complacently considered a boom quite the normal thing, only to bewail the abnormality of the succeeding depression that their complacency brought on.

Striving for a fallacious simplicity of statement, economists have sacrificed clarity of thought in formulating so-called "economic laws." The subjective method developed a formalism that led men to believe that the so-called law of supply and demand was something external, universal, and automatic in its operation like the law of gravity, and that business simply consists of fabricating goods and making a price that takes the goods into consumption. The business world never could and never will recognize that sort of purely imaginary market.

Every business man knows that fabrication is not difficult but that sale at a profit is. It is not impossible to start a new automobile factory and make a better car at a lower cost than the "flivver," because the limit of invention is not yet in sight and Mr. Ford is still a human being, in spite of all attempts to deify him. Suppose such a factory were started, and its owner, counting on the automatic operation of the law of supply and demand, were to make a lower price than Ford's, and just wait for customers. Would he find Emerson right, that clamorous buyers would beat a path to his door, elbowing each other out of line to secure one of the new cars? Personally, I would wager that the Ford sales organization would put more "flivvers" on the road, and at a higher price.

Again the usual generalization is fatally defective when a depression comes on, when nobody wants to buy at low prices; or when a boom develops, when every one wants to buy at high prices. The usual explanation of these things is, "Well, that is abnormal; it just cannot be explained by the formula." Another important fact is that the relative elasticity or inelasticity of demand in its response to price movement is vitally different for different commodities at all times, and is different for the same commodity at different times. Economic theory has concerned itself but little with the effects of this inelasticity in different businesses.

England's leading economist, Alfred Marshall, seemed to think that only in the case of a coffin maker working for a local poor house would it be impossible to stimulate demand by lowering prices and that with this limited exception, the law as formulated by him is universally true. Yet manufacturers of industrial machinery of all kinds, whose yearly sales amount to hundreds of millions of dollars, are precisely in the same boat with this coffin maker, and unless they manage their business craft according to actual facts and not by generalized errors they are sure to lose their ventures. The whole mechanical engineering profession is largely effected by this little considered but very important characteristic of inelasticity of demand for some goods.

Making plant equipment of all sorts constitutes a very large part of total production from year to year, and each year it constitutes an increasing part. How many engineers recognize that such a business cannot be continuously operated according to the notion of a "normal," because of the nature of its demand? Demand for production machinery is entirely secondary, dependent on the demand for the product of the machine, and becomes effective in orders from three sources:

1 From wear-out
2 From expansion in the market for the machine's product
3 From improvement of the machine reducing the cost of the product.

Unlike demand for food and fuel there is little recurrent demand arising from wear-out or consumption of machinery. Well-built machines are relatively long-lived so that actual wear-out is slow, and as improvement is always proceeding there is a diminishing market each year for old types of machines. Expansion demand comes on only when the machine builder's customer is starting a new shop or is making additions to his capacity to take care of prospective increases in his own demand. This is done only well along in the prosperity stage of a business cycle, and it stops before the boom is over, as soon as the user sees his own temporary satiety point looming up. Obsolescence or improvement demand is largely an expansion demand, since it involves greater production per machine. Expansion demand comes on late in the cycle because most men lack both the money and the courage to expand their plants during depression. The consequence is that a machine industry's order curve would show relatively sharper peaks and wider valleys than consumer goods demand would show. For good reasons, until the particular cycles of the machine-using industries are controlled, buyers will mostly continue to place their orders in that fashion, and will not be tempted by the low prices made in a depression to do otherwise. The machine builder and his employees can feast only as the buyer spreads the feast.

Not knowing much of the practical effects of this inelasticity, but assuming that all demand can be made to respond in the same theoretical way to a reduction in price, Prof. John R. Commons

gravely proposes an absolutely uneconomic scheme, falsely but attractively labeled "unemployment insurance." It is not insurance at all, because it does not distribute the risk of unemployment over a considerable base or over a considerable time. It concentrates the risk on the last employer unfortunate enough to be compelled to lay off a workman at a time when jobs are scarce in his locality and industry.

Certainly conditions of demand and supply for machinery are decidedly different from those for butter. So even though this scheme which it is proposed to apply to all employers alike, might work no great hardship on a butter manufacturer, that is no good premise for a conclusion that its effects would be beneficial in the machine industry. Such superficiality is coupled with a praiseworthy desire to do a really constructive thing—to provide a reserve out of which workers can better support a business depression. But the good motive does not cure the bad logic that is being used to further this uneconomic legislation in Massachusetts and Wisconsin at this time.

Is it any wonder that business is not "sold" on that kind of economics? Can business be blamed for scoffing when such manifest fallacies are gravely put out for public consumption by an economist of some standing without much, if any, criticism from this confrerès? Unfortunately it is just such economic stuff-and-nonsense that attracts the attention of the unthinking mass and arouses their interest. It is easy to create desire for something that looks so easy to get—at some one else's expense— and to induce legislative action regardless of logic and real economics. And so the sale is made—here and in Russia. Then, when private initiative is so hampered that industry withers, the public finds—too late— that it was "sold" —in the sense the bunco man uses the term "sold."

Good economics does need selling of the right kind, to replace the spurious goods mostly current on the market. To do that sort of selling will require men of the engineer type, who are now preferred to the superficial hand-shaking type where any project of importance is under way. The engineer salesman with a professional, scientific background knows his goods and their application, and knows how to engineer the sale. I believe that when the engineer takes up economics seriously he will want to "sell" it to business, and he will keep business "sold on economics" in the proper way. As the engineer is essentially one who carries out the application of other sciences in the furtherance of human welfare, perhaps we would call this class of man an Economic Engineer.

Discussion by President-Elect Harrington

There is being carried out before us today one of the greatest experiments the world has ever known in the endeavor to level all standards of living to one common standard, to be applied to all the people. A large portion of the Russian people, however, have been disillusioned in regard to the possibility of doing that. The theoretical governments that have been set up in like fashion have all failed whether on a large scale or small scale, and their endeavor to level the standards of living and to adopt uniform production and consumption has failed.

The support given to these ideas has resulted from reasoning from the particular to the general—the endeavor to establish general laws from a theoretical consideration of individual cases. The economist must, of necessity, establish his general laws in that fashion. The result has been that in this country recently a number of pronounced errors have been perpetrated in the endeavor to apply to the nation as a whole deductions made from a few individual cases, without regard to locality or local conditions.

The organized workmen have sought vigorously to reduce all wages and all returns for labor to a common standard. And during the late unpleasantness with Germany, when our Government was concentrated in the hands of a few, and operated in a very arbitrary manner for the sake of winning the war, advantage was taken of that situation to establish by law certain uniform standards of payment, not standardizing the living, but standardizing the payment.

Out of that condition there has arisen the idea on the part of organized workmen that a standard of living could be established that should be adopted and used throughout the country. And it has further been contended that something like $2000 a year is necessary to sustain in reasonable American fashion the theoretical family of five of the workman, and various endeavors have been made to extend the view that that rate of payment is essential in probably our greatest industry, that of transportation.

It therefore has been brought about that in some portions of this country today the standard wage fixed by law or by the regulation of a commission is double in that particular industry what it is in corresponding industries in like localities. It is an absurdity to apply the same rule in those portions of the country where food and living conditions are comparatively cheap as in those portions where they are comparatively dear, for excess wages paid to any group in any community are paid at the expense of the other members of that community.

It would seem, therefore, that in studying the welfare conditions in this country we have got to consider very carefully the question of differences in locality. For example, it is very difficult to convince the southern tenant farmer, who has never received as much as $500 a year and has a poor little house to live in, that his fellow in the same community employed on a railroad is entitled to three or four times that wage. He knows that a rank injustice is being done by law.

It would be very simple if we could only reduce all of the general laws to a common formula, applicable to anybody and everybody: it would avoid thought and effort. But we must deal with the narrow, with the individual case and bring up the standards of living in some portions of our country, which are entirely too low at the present time—too low for a wise government and for the wise development of our people; while in others there must be repressed the tendency to secure more than rightfully belongs to them.

It is high time that we addressed ourselves carefully to a broad consideration of the differences in the living conditions of the people of the various parts of the United States, and the rightful compensation which they should receive. We cannot possibly afford to let living conditions go on as they are and have been going on in certain portions of the United States where they are so low that the character of the population is far below the American standard. These conditions, strange to say, do not prevail so much in our larger cities as in the poorer agricultural districts, where education is scanty, where it is difficult to train the people to think about their own condition or to reach them, where the citizenship is widely scattered and it is hard to bring them into a common condition for their own benefit, and where organization is out of the question. The city problems have had many times the study put upon them and are in course of solution, but the problems of our scattered and backward agricultural population are not receiving the consideration their importance warrants, and more attention should be given to them by economists and engineers.

Discussion by Past-President Fred J. Miller

In the development of our modern economic and industrial life we have gotten in some way too far away from the conditions that obtained in the earlier and more attractive forms of industry. The nearer we can get to a simpler ideal in the development of industry, the nearer we shall get to solving many of the difficulties that now confront us in our industrial civilization. I believe in the conditions of economic freedom with a natural leader of the shop to mass the helpers or employees, so that they can, as a group, do better work—and with more profit—than they could do working as individuals, each applying his labor to the materials of nature for the support of himself, working for himself and devoting all his efforts to his own benefit.

Our modern system develops leaders of that sort to a great extent, but at the same time we have drawn into the development of our industrial life certain restrictions around that very association that would not take place under simpler conditions, and I believe that it would be desirable to find some way of doing away with these restrictions, so that these natural associations would come about more readily. The leader, even under those conditions, would be adding to the value of the labor of every man under his direction and would thereby receive the larger reward that is due, and properly due, those capable of directing large operations, who should be liberally paid for their services. There would then be no doubt that each man working under such a leader was receiving what was his due, and that the man who did the leading was receiving what he should fairly and rightly expect.

Developments in Stoker Practice

ONE of the outstanding features of the 1922 Annual Meeting of The American Society of Mechanical Engineers was the well-attended and closely followed joint session of the Fuels Division of the Society and the Stoker Manufacturers' Association, held on Wednesday, December 6. At this session three papers were presented dealing with the various types of stokers that have been developed for the firing of boiler furnaces: namely, The Development and Use of the Modern Chain Grate, by T. A. Marsh; Overfeed Stokers of the Inclined Type, by Geo. I. Bouton; and The Design and Operation of Underfeed Stokers, by H. F. Lawrence. A Chronological History of Stoker Development to the Present Day, by A. H. Blackburn,[1] was also presented at this session. Extended extracts from the three papers dealing with stoker practice immediately follow.

The Development and Use of the Modern Chain Grate

By T. A. MARSH,[2] EAST CHICAGO, IND.

After discussing the need of progressive combustion of the several constituents in coal, and the variations in grate designs to handle different coals, the author takes up the improvement of chain-grate practice as regards air-tightness, cooling, size of combustion space, etc. He shows how a greater boiler capacity can be obtained by increasing grate size or by more intense natural or forced draft (0.50 to 0.60 in. for a combustion rate of 40 to 45 lb. per sq. ft. of grate per hour), but states that high and sudden overloads are best met by forced-draft chain grates burning 55 to 60 lb. of bituminous coal per sq. ft. per hour, with air at 2 in. pressure distributed through compartments between the runs of chain. He describes such equipment, and states that 200 per cent of rating can be reached in 8 min. from a short-banked fire, or in 52 min. from a cold grate. The paper concludes with a table of results obtained in a number of stations equipped with chain grates.

ANY STUDY of the adaptability of various stoker types and their proper functioning as fuel burners must start with an analysis of four constituents in coal, namely, moisture, volatile, fixed carbon, and ash; or roughly, water, tar, coke, and dirt. These constituents are so dissimilar that each must be differently treated in the combustion process, and specific means for burning them in proper sequence must be provided in stoker and furnace design. These facts at once determine as fundamentally correct those types of stokers embodying the principles of progressive combustion, by which is meant in practice a continuous movement of coal through the furnace and the providing of definite treatment at proper time and place for the burning of each constituent of the fuel.

Chain grates embody the principles of progressive combustion. As coal is fed into the furnace, the moisture is vaporized; then the volatiles are distilled and burned in suspension, followed by the burning of fixed carbon. Finally the ash is discharged over the rear, and the air space of the grate is automatically cleaned for a repetition of the process.

Variations in the proportions of these constituents are seen in coals from different sources. Some coals are more free-burning, others tend toward coking. Some have high percentages of ash, others less. Differences as to clinkering or non-clinkering are noted. Such variations at once emphasize the fact that no one stoker and furnace can be suitable for all coals. Stokers and furnaces adapted for progressively burning certain coals must be modified if they are to be used for burning other coals having widely different proportions of characteristic constituents.

Free-burning coals burn best when the fuel bed is undisturbed; coking coals demand fuel-bed agitation. High-ash coals demand continuous scavenging of refuse from the grate; with low-ash coals this is not necessary. Clinkering coals must not be agitated, or clinker formations will result. With non-clinkering coal, agitation has a less detrimental effect.

Chain grates were first developed to burn high-volatile, free-burning, high-ash, clinkering coals. For such coals they offer in best form the specific combustion treatment demanded by their characteristics. The fuel bed is undisturbed, making this stoker type suitable for free-burning and clinkering fuels. The ash is continuously discharged from the grates, which is necessary for continuous operation with high-ash coals.

The development resulting in the modern chain grate has been gradual but definite, and has involved the successful burning of many coals having far different characteristics. All successes, however, have been dependent upon the application of the principles of progressive combustion. Coal burning in any practical process involves some losses: a total conversion of the heat in coal into heat in steam is impossible. Costs of operation must also be considered. These facts determine that every combustion process must finally operate with a common-sense balance between the three important factors in steam-generation economy: namely, maintenance, efficiency, and capacity.

Maintenance and Efficiency

Maintenance and reliability are closely related. The chain grate, with two-thirds of the grate surface out of the furnace and with a simple driving mechanism, was always low in maintenance costs. In the earlier designs, however, some parts were exposed both to heat and wear. Parts necessarily exposed to wear or strain often did not have sufficient resistance.

The chain, which is the fuel-carrying part, is now subjected to but slight heating as a result of adequate ventilation. Stoker frames are not subject to wear and are not exposed to heat. When exposed to heat or wear, replaceable parts are provided.

The high fuel costs of recent years, combined with a broader knowledge of combustion principles, have led to the development of features for improving efficiency. Inasmuch as chain-grate stokers have always involved very low auxiliary power consumption—about 0.5 hp. per stoker—all results obtained are practically net, and little improvement could be hoped for in that direction. Efforts were therefore directed toward the elimination of other losses, such as excess air, and to the reduction of furnace and ashpit losses.

Improvements in Grate Design

Air Leakage. A grate surface moving through a furnace presents the problem of air seals along the sides of stoker and at the rear. The reduction of air leakages at these places has contributed materially to modern economy.

Overhanging bridge walls and water backs are necessary. All attempts to approach efficient combustion without water backs have failed. Many designs of water backs were tried, resulting finally in the modern water back connected into the pressure circulation of the boiler. Water backs are successful only to the extent that they close the openings and eliminate air leakage between the bridge wall and the fuel bed.

Ledge plates or seals along the sides of the stoker went through a similar development, resulting in the modern adjustable ledge plates for making a proper rubbing seal with the stoker chain, and including means for adjustment to keep this seal intact.

The development of the ledge-plate flange adjustable against the side of the upper chain made it possible to raise and lower the stoker to vary the discharge opening under the water back in order to meet broad changes in fuel conditions. The improved results thus obtained indicated the desirability of a water back adjustable as to height, and several designs were developed. These were for the most part difficult to construct or to maintain. From such designs the modern fuel retarder was developed. This is an adjustable member in connection with a fixed water back and bridge wall.

[1] Chief Engineer, Under-Feed Stoker Co. of America, Detroit, Mich. Mem. Am.Soc.M.E.

[2] Chief Engineer, Green Engineering Co. Mem. Am.Soc.M.E.

The fuel retarder can be raised or lowered to make a definite air seal with the fuel bed.

Sifting of coal through the grate often amounted to from 5 to 10 per cent of the coal fired. The use of longitudinal skids to carry the chain in place of cross-rollers has reduced the siftings to 1 or 2 per cent, and in addition to labor saving a more uniform fuel bed results.

Furnace Design

Simultaneous with the development of the stoker has been that of furnace design. Furnace volumes have been quadrupled during the last 10 years. Modern chain-grate furnaces have 2 cu. ft. of furnace per developed horsepower. Losses due to unburned hydrocarbons have been greatly reduced. Formerly a rating of 150 per cent was exceptional. However, modern high-set arches with ample draft and adequate furnaces permit high combustion rates and high ratings from boilers.

Improved furnaces, proper draft, longer arches, water backs, and fuel retarders have all contributed to the reduction of ashpit losses. High stoker and furnace efficiency is dependent, not on a minimum of any one loss, but on a minimum sum of the losses due to excess air, ashpit loss, and unburned hydrocarbons. The modern chain grate and furnace permit adjustment and continuous operation, with the aggregate of these losses a minimum.

Chain grates are ideally adapted for producing smokeless combustion, due to the uniform feed, uniform fuel bed, and the arch. With modern furnaces and proper air control, smokelessness within the capacity of the furnace can be assured even with the high-volatile smoky coals of the Middle West.

Capacity

Modern steam turbines called for greater capacities from boilers. This demand was met in the chain-grate field by development along three general lines: namely, higher drafts, larger grate surfaces, and forced draft.

Higher Drafts. Chimney heights for natural draft were increased to 200, 250, and even in excess of 300 ft. Many plants installed induced-draft fans. Furnace drafts of 0.50 to 0.60 in. were obtained, and combustion rates reached figures of 40 to 45 lb. per sq. ft. of grate surface per hour.

Larger Grates. This rate of combustion seems to be about the limit of natural-draft performance. Efforts to obtain higher ratings have led to larger stokers. Stokers were built up to 18 ft. long, with ratios of grate to heating surface increased to 1 to 30. With such grates and high draft, boiler ratings up to 200 per cent were possible.

Forced Draft. The need of still higher ratings, particularly with low-grade coal, brought the application of forced draft to the chain grate. Early installations applied forced draft at uniform pressure under the entire grate surface. This increased capacity but did not control excess air. Forced draft under a fuel bed with the slightest tendency toward thin spots caused excess-air losses, chilled the furnace, and reduced capacity.

The logical development for air control was to divide the stoker into compartments and control the air supply to each compartment.

The forced-blast chain-grate stoker has been in commercial use for some twenty-five years, and in successful use for approximately ten or twelve years in the anthracite-coal regions, but it was not until five or six years ago that any really successful installations were made for burning bituminous coal.

This stoker consists of a continuous or endless chain of links or grate bars traveling over front and rear sprockets. Side girders are used in some cases, but in others are entirely omitted and transverse members forming compartment sides and wall supports substituted therefor. Above the front sprockets is a sizeable coal hopper, and at the back of this hopper a stoker gate which can be raised or lowered to vary the thickness of the fuel bed on the grate.

The stoker is usually set in an extension or Dutch-oven furnace the arch of which radiates its heat on the incoming fuel under the stoker gate and causes i to ignite, the fire gradually burning down through the fuel bed until it reaches the grate. The thickness of the fuel bed is governed by the character of the coal burned, the length of the stoker grate, and the capacity at which the stoker is to be operated. With the same grate, and with different grades of coal or different capacities the fuel bed may vary between 5 in. and 9 in. in thickness.

Size of Forced-Draft Stokers

The length of the stoker, which should be taken as the distance between the inner face of the stoker gate and the sealing plate of the rear blast compartment, is varied somewhat to conform with the type of boiler under which the stoker is installed, and with the rate of combustion which is desired. Very few forced-draft chain grates are less than 12 ft. in length, but only in exceptional cases do they exceed 20 ft.

The width of the stoker is usually made slightly less than the boiler-furnace width, so as to afford column protection. Single stokers practically the full width of the furnace have been built, even for the wide central-power-station boilers now so popular. There are forced-blast chain-grate stokers in operation today that are 24 ft. in width, and widths of 27 ft. to 30 ft. are under consideration.

Various types of links are used with the forced-blast chain-grate stoker. Regardless of the type, however, the design of the link is such that relatively fine jets of air are admitted through the grate, and a uniform air distribution is applied to the fuel bed from any given blast compartment.

The forced blast is usually admitted into five or six compartments formed between the runs of the chains. These compartments are sealed from one another, and dampers or slides are arranged so that the blast to any one compartment may be regulated independently of that in any other. Some designs are so constructed that any compartment can be operated on forced or natural draft, or closed off entirely, and so that the change from one to either of the other conditions of air supply can be made simply by the operation of a single adjustment lever.

As the coal is burned, the resistance of the fuel bed decreases toward the rear end of the grate, and the air pressure is varied in the different compartments to meet the requirements and effect proper combustion at any given point with the least excess air. It is possible to use only half or three-quarters of the grate length when operating the stoker at low capacities and still maintain a comparatively high rate of combustion on the front portion of the stoker.

The blast pressure in any one compartment rarely exceeds 2 in. water pressure, even at a combustion rate of 55 to 60 lb. of coal per sq. ft. of grate surface. Low-pressure designs obtain similar combustion rates with about one-third of this pressure. The highest pressure is usually carried in the second and third compartments from the front of the stoker, as it is at these points that the fuel bed on the grate is completely ignited and the maximum rate of combustion takes place.

The blast to each compartment is regulated by heat control. The amount of blast used under the grate and the speed at which the stoker chain travels are the factors that usually determine the capacity at which the stoker may be operated with a given thickness of fuel bed.

Combustion Arches

Stokers installed for the burning of the Central States high-volatile coals have ignition or combustion arches set about four feet above the grate at the front end, and somewhat higher at the inner end. These arches cover approximately 50 per cent of the length of the stoker, are of the suspended type, and are made from high-grade refractory material.

Stoker installations for the burning of the low-volatile high-carbon bituminous coals of the Eastern States use a shorter arch, covering about 30 per cent of the stoker length but set at practically the same height above the grate as for the high-volatile coals. Arches set at this distance above the grate require a short ignition arch, 12 to 18 in. in length, at the stoker gate, and set 18 to 24 in. above the grate. The increased rate of combustion obtained with forced-blast chain grates necessitates a better grade of refractory for the entire furnace lining.

Various schemes are being considered today for cooling the furnace side walls of all the different types of stokers operating at high rates of combustion, with the purpose of reducing furnace

maintenance costs. Of these various schemes those employing water-cooled members will undoubtedly prove the most successful, because of positive functioning.

Prevention of the formation of clinkers at the fire line on the side walls is a problem separate and distinct from reducing side-wall maintenance. Some manufacturers are using specially designed firebrick blocks at the fire line, through which blast from the blast duct enters the furnace. The air passing through these blocks keeps them cool and prevents clinker from adhering to them. Other manufacturers are using side-wall water boxes at this point, some of which are connected into the boiler circulation, while others are independently connected.

The bridge-wall water back is a part of the standard stoker equipment with several of the forced-blast chain-grate stokers. This water back is carried transversely across the rear end of the stoker 3 to 7 in. above the grate, and acts not only as an air seal at this point but protects the bare links of the stoker from the reflected heat of the bridge-wall brickwork.

TABLE 1 FUELS USED AND RESULTS OBTAINED IN ELEVEN BOILER PLANTS EQUIPPED WITH CHAIN GRATES

Description of Station	Location	Name of Coal Used	Moistu r cent	Ash, per cent	Volatile, per cent	Fixed Carbon, per cent	Sulphur, per cent	B.t.u. per lb., Commercial Basis	Average Rating, per cent	Maximum Rating, per cent	Banked Boiler Hours, per cent	Economizers	Combined Efficiency of steam-generating unit, per cent	Time covered
Central station [1]	Middle West	Illinois	14.5	16			4	10000	225	275	8	Yes	73.6	3 months
Central station	Middle West	Illinois	14.5	16			4	10000			30	50 %	69.1	3 months
Central station	Southwest	Kansas	4.66	11.7	33.05	50.62	4.2	10561				No	69.4	24 months
Central station	West	Iowa	16.51	18.72				8891	180		32	No	73	12 months
Central station	Middle West	Indiana	9.8	17.7	33.3	49	4.2	10000	170	230	30	No	70	12 months
Steel plant	Middle West	Indiana	18	12.2	35.2	52.6	2.20	10150	140			No	71	12 months
Steel plant	Pittsburgh district	Pennsylvania	2.09	10.5	33.7	55.8	1.60	13250	107			No	69.4	12 months
Central station	West	Colorado	23	12.5	32.5	32	0.20	8865				Yes	72	1 month
Central station	West	Kansas	6	19	27	48		10700	130	200	49	50 %	69	1 month
Central station	Middle West	Ohio&Penn.						11766	145	225	6	Yes	73.8	5 months
Central station [2]	Middle West	Illinois	14.5	16			4	10000	271			Yes	78.7	1 month

[1] Part of the stokers in this plant are forced-draft units.
[2] All of the stokers in this plant are forced-draft units.

Results Secured

The forced-blast chain-gate stoker is particularly adapted to the use of free-burning coals that require agitation of the fuel bed to break the crusting or caking action so often encountered with the slower-burning coking coals.

With free-burning coals, which usually run high in sulphur and have an ash with a low fusing point, results are being obtained, with uninterrupted operation, that equal the results obtained with other types of stokers using the low-volatile high-carbon coals.

When burning No. 3 buckwheat or coke breeze, fires 3 to 6 in. in thickness are carried on the grate and sufficient blast is carried in the first and second blast compartments to cause a gentle boiling or dancing of the fuel bed. Care must be taken, however, to regulate the thickness of fire and the blast so that excess carbon monoxide is not produced and continued combustion carried through the boiler to the chimney.

The forced-blast chain grate may be operated at continuous high overload capacities for days at a time with only slight variations in the steam output of the boiler. This operation is made possible by the uniform thickness of the fuel bed, the uniform blast pressures carried, and the uninterrupted disposal of ash and refuse from the grate. Such stokers may be operated efficiently under natural draft when burning as little as 10 lb. and as high as 35 lb. of coal per sq. ft. of grate per hour. Forced-draft combustion ratings reach 55 to 60 lb. of coal per sq. ft. of grate per hour.

The forced-blast chain grate is simple to operate and flexible in handling varying load conditions. If properly handled it can be brought from banked fires to full load in time to meet any ordinary power-plant requirements. A cold boiler can be put on the line in 45 min. from the time of lighting the fires. The boiler can be operating at 150 per cent of rating in 5 min. from the time it goes on the line, or it can be operating at 200 per cent of rating in 7 min.

With the ordinary short-banked fire, which consists of a bed of coal three to four feet in from the stoker gate, the remainder of the grate being bare, the boiler can be brought up to 200 per cent rating within 25 min., while with the long bank, in which 50 per cent of the grate is covered with fire, the boiler can be brought up to 200 per cent rating within 6 to 8 min.

Automatic control has been successfully applied to both natural- and forced-draft chain grates. With natural-draft chain grates the usual control is by means of a steam-pressure or steam-flow regulator controlling the boiler damper and the speed of the stoker engine or motor. With forced-draft chain grates several control systems are in successful service. The electrical control is applicable on motor-driven installations. The steam-flow regulator controlling the air supply to the stoker and the speed of the grate is giving successful results.

The steam-pressure regulator controlling the air supply to the stoker and speed of the grate is also giving excellent service. In case constant furnace draft is desired, the balanced control can also be applied, as is frequently done with the two latter-mentioned systems.

Natural Draft vs. Forced Draft

Whether natural- or forced-draft chain grates should be installed depends upon the conditions in the individual plant. The station load, banking periods, boiler absorption with or without economizers, as well as the limits of the draft available, are all involved.

Natural-draft chain-grate stokers, within the limits of the draft available, produce cheap steam. Low auxiliary power requirements, low maintenance, and controlled loss in the combustion process, make low cost of steam inherent.

Natural-draft stokers should be installed:

a Whenever the capacities demanded to meet the station load are within range of the natural draft available

b Whenever the load demand is steady or where peaks can be anticipated sufficiently far ahead to permit building up furnace conditions to meet them

c Within the limits of the above two conditions, whenever induced draft and economizers are used.

In Table 1 the author submits some long-period operating figures from chain-grate power stations. While the compiling of such figures by power stations is subject to variations in the methods employed for that purpose, the figures in question nevertheless must be accepted as part of the operating records of large and reliable companies having engineering departments competent to compile such records.

Overfeed Stokers of the Inclined Type

By GEO. I. BOUTON,[1] DETROIT, MICH.

In this paper the author discusses the development, present construction, and method of operation of the front- and side-feed types of inclined overfeed stokers. Several side-feed stokers are described, with an illustration of a Dutch-oven type of setting. It is stated that 200 per cent of boiler rating can be obtained with 0.3 in. to 0.5 in. draft loss through the fuel bed, and that when forced draft is applied, it should be done with proper regard to air circulation and the maintenance of suction above the fire. Front-feed stokers are also described, with an explanation of combustion control by varying the stroke of the coal pusher and the angle of rotation of the bars. The effect of the flux content of ash in determining the fusion temperature is also discussed.

STOKERS of this type are of two general classes, the side-feed double-inclined or V-type, and the front-feed or single-inclined stoker. The early development of these stokers was along natural-draft lines, because that was the draft available and because it was possible to readily burn all the coal required to meet load conditions. As the steam plants have increased in size, the boilers and stokers have also increased in size until this type has apparently reached a limit in a stoker having a projected grate area of 100 to 110 sq. ft. in a single unit, capable of burning sufficient coal, under forced draft, to develop about 2000 b.hp. as a maximum.

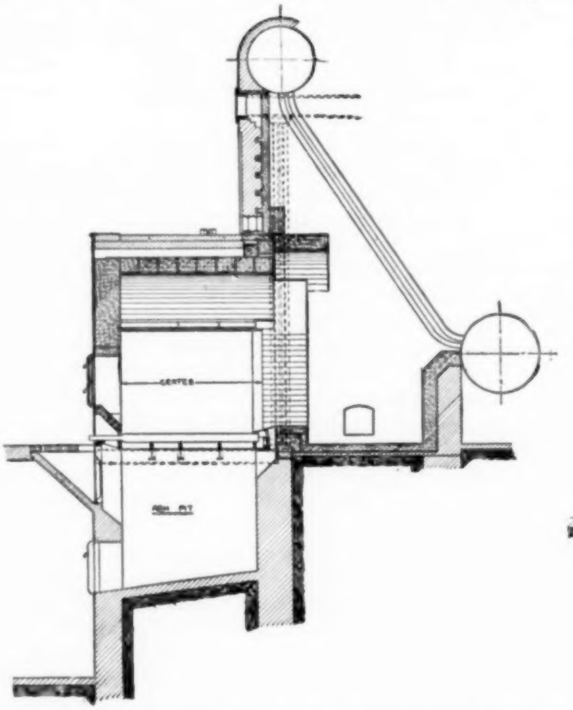

Fig. 1 Typical Dutch-Oven Setting for Side-Feed Double-Inclined Overfeed Stoker under a 500-Hp. Stirling Boiler

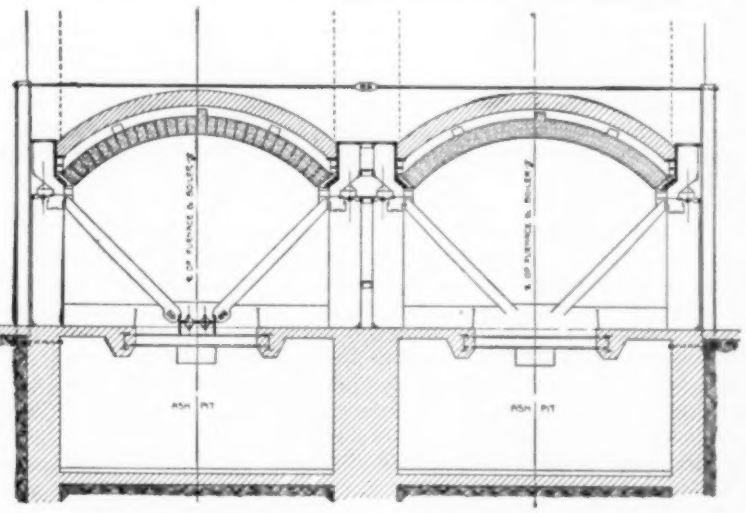

Fig. 2 Typical Dutch-Oven Setting for Side-Feed Double-Inclined Overfeed Stoker under a 500-Hp. Stirling Boiler

The double-inclined side-feed stoker was the first to make its appearance in this country, Thomas Murphy fathering this particular line of development, commencing about 1875. His first attempt, which was hand-operated, was placed in the firebox of a marine boiler and had inclined grates, every second grate being movable. It was provided with a revolving toothed cylinder or clinker grinder extending from front to rear along the bottom of the V, for the removal of clinker and ash.

In 1879 Murphy moved this device forward into a Dutch oven for use in connection with a return-tubular boiler, and added magazines and stoker boxes for feeding coal to the upper end of the grates. He placed a firebrick arch above the entire grate surface, with a second arch enclosing an air space above the arch and with provision for circulating air for combustion over the firebrick arch and through openings in the arch plates immediately above the fire, at the point where the volatile gases are distilled from the coal. About 1880 he provided an engine drive, placing a reciprocating bar across the front of the stoker, with arms and links to operate the stoker shafts which moved the stoker boxes back and forth, and the rocker bars which raised and lowered the movable grates, and with a ratchet which rotated the clinker grinder. In all essential features this stoker is the stoker of this class of the present time, as represented by the Murphy, Detroit, and Model stokers, although there are many minor changes in the stokers as built today.

About 1885 the front-feed inclined stoker was developed, the Roney and Brightman stokers being brought out at that time. The Brightman stoker was apparently not a financial success and it gradually disappeared; a modified form of it, however, still remains in the Wetzel stoker.

Originally the grates in the side-feed stokers were set at an angle of 35 deg. with the horizontal. As the size of the stokers was increased this angle was increased to 40 deg., and later to 45 deg., which is the present standard. Grates at this angle are suitable for bituminous and semi-bituminous coals. With non-coking coals a much flatter grate is desirable, and when coals of this sort are to be burned it is advisable that the stokers be designed particularly for the coal in question. The grates in the Roney stoker are at an angle of 35 deg. with the horizontal, and this stoker will burn anthracite and bituminous coal and lignite. The grates in the Wetzel stoker are also set at the same angle.

Where wood refuse or spent tanbark is used, this is usually burned in connection with bituminous coal, enough coal being burned to keep the grate surface covered. Wood refuse is spouted to the stoker through an opening in the stoker front, or dropped through openings in the arch directly on to the fuel bed. Tanbark is usually mixed with the coal and fed to the stoker in the regular way, that is, through the magazine or hopper. Spent tanbark will run about 60 per cent moisture, and when a half-and-half mixture is used about 85 per cent of the heat supplied to the boiler will be from the coal, the remainder from the tanbark.

Side-Feed Double-Inclined Stokers

The side-feed double-inclined stoker may have either a flush-front or Dutch-oven setting. The flush-front setting is limited to the smaller return-tubular boilers and horizontally-baffled water-tube boilers. On the larger return-tubular boilers, vertically baffled horizontal water-tube boilers, and boilers of other types it is advisable to place the stoker in a Dutch-oven setting. A Dutch-oven setting materially simplifies the matter of supplying coal to the stoker, and where desirable an eight or ten-hour supply of coals can be stored on top of the stoker. A typical Dutch-oven setting is shown in Figs. 1 and 2.

[1] Chief engineer, Murphy Iron Works. Mem. Am.Soc.M.E.

These stokers are made in various sizes, both as to width and depth, varying from a stoker with a grate surface 4 ft. wide and 3 ft. deep to one having a grate 12 ft. wide and 9 ft. deep. In the larger stokers 1 sq. ft. of projected grate is provided for each 6 1/4 rated horsepower of the boiler, and in the smaller stokers 1 sq. ft. for about each 5 rated horsepower. Where the stokers are set with a Dutch oven they extend in front of the boiler about the depth of the grate surface of the stoker, this being varied to suit local conditions and the details of the boiler. The overall width of the stoker is roughly the width of the boiler setting. The head room required will vary with the width of the stoker. The boiler should be set sufficiently high so that the front header or the sill of the tube-door opening clears the top of the arch about 3 in. This would mean a height of about 6 ft. on a 100-hp. boiler, 7 ft. 9 in. to 8 ft. 3 in. on a 300-hp. boiler, and 11 ft. 3 in. on a 600-hp. boiler. Where vertical water-tube boilers are used, such as Wickes, Rust, or Erie City vertical, it is advisable to place a combustion space between the rear of the stoker and the tube surface of the boiler. This can be made of somewhat greater cross-section than that of the stoker. The distance from the rear end of the grate surface to the tube surface should be 6 or 7 ft.

Stokers of this class are usually driven by a small steam engine operating the reciprocating bar through a chain of gearing. Where for any reason it is desirable to do so, a motor, either a.c. or d.c., can be used in place of the engine. An engine is preferable to a motor, however, as the exhaust steam which it supplies is useful under the clinker grinder.

As far as the author knows, the most convenient and effective means of chilling clinker so that it can be readily handled is by means of low-pressure steam discharged under both the clinker grinder and the lower ends of the grates.

It is desirable that the fuel be fed as uniformly as possible to the stoker. The fuel bed is about 8 to 10 in. thick at the upper end of the grates, thinning down gradually toward the clinker grinder. Minor fluctuations in load should be taken care of by minor variations in the draft over the fire. Where the load changes into a decidedly higher or lower range, the coal feed should be increased or diminished to meet this range, the draft over the fire being regulated to take care of the immediate needs of the boiler.

The draft loss through the fuel bed will vary with the amount and kind of coal being burned, the high-volatile coals requiring less draft than the lower-volatile coals. The amount of draft required is also affected by the amount and kind of ash which the coal carries. Where proper draft is provided, stokers of this class will take care of various loads readily up to 200 or 225 per cent of boiler rating, although the draft available usually limits the capacity to 200 per cent of boiler rating or less. Where there is a shortage of draft it is possible to compensate for this in part by increasing the amount of "rousting" or hand manipulation of the fuel bed. At two per cent of boiler rating the draft loss through the fuel bed will vary from 0.3 to 0.5 in. water gage, depending on the kind of coal and the amount of rousting.

Where it is desired to obtain more capacity than can be obtained with the natural draft available, it is sometimes possible to do this by adding forced draft. Where forced draft is applied to a stoker of this class, it is advisable to see that all the necessary items for its proper installation are taken care of. The air should be admitted to the space beneath the grates, either at the front or the rear, in a line parallel with the clinker grinder; two inlets being used, placed symmetrically with reference to the center line of the stoker. Instances have been found where a blower has been placed through each side sheet, discharging air directly against the grates, and troubles have quickly resulted from such practice. Under natural-draft conditions the amount of air reaching the furnace through the openings in the arch plates increases as the capacity increases, and provision should be made so that this same condition holds good under forced-draft conditions.

The limit of capacity under forced-draft conditions will be that point where the draft over the fire is so reduced that fire is blown out of various openings. This will be when the draft over the fire is reduced below 0.10 in., probably to about 0.05 in.

With forced draft properly installed and skilful firing it is possible under favorable conditions to get in the neighborhood of 300 per cent of boiler rating. The fires are rather thin for forced-draft work and it requires closer attention to the fuel bed to keep the grates covered than in the case of stokers using a much thicker fuel bed.

Where these stokers are operated under natural-draft conditions the proper method of regulating the air supply is by adjusting the damper at the outlet of the boiler. This can be done by hand where necessary. There is no objection to using a damper regulator provided it reproduces the action of a skilled fireman as closely as possible and shifts the damper slightly with varying steam pressure.

Front-Feed Inclined Stokers

Of the many forms of front-overfeed inclined stokers which have appeared, the Roney and Wetzel are still being built. The Roney is a natural-draft stoker only. It is made up of an inclined grate with transverse bars. Each bar is supplied with sectional grate-bar tops so arranged that they allow a uniform distribution of air through the whole grate area. At the upper end of the furnace, flat fuel plates are provided on which the coal can coke, and this prevents sifting of the green coal until the coking process is well under way; by this time there is no further trouble with siftings. There is an agitation given to the grates by a rotary motion of the transverse bars. This motion feeds the refuse and fuel uniformly toward the lower end of the grates. At this point and immediately above the dump grates there is an agitator for the purpose of breaking up clinker that may form in this zone; it also serves the purpose of preventing the avalanching of the fuel bed down the grate while the dump grates are open and the fire is being cleaned. The dump grates are slotted, thus providing active fuel-burning surface in this zone.

The angle of rotation of the transverse bars can be varied from nothing to a maximum. The stroke of the coal pusher can also be varied. The ability to control these motions without changing the speed of the engine provides a very wide range of flexibility. It is customary practice to operate Roney-stoker driving units at constant speed, and take up the fluctuation in the rate of feeding coal by means of the variable adjustments on the stroke of the coal pusher and grates. Motors or reciprocating engines are usually supplied for driving Roney stokers. The whole stoker-driving mechanism is extremely simple, as a multiplicity of stokers can be driven from one shaft for both the feed and grate motion.

The thickness of the fuel bed on a Roney stoker is uniform for a given grade of coal and does not vary for different ratings. The best practice is to control the rating on the boiler as desired by means of the boiler damper and not by thickening or thinning the fuel bed.

The Roney stoker is applicable to any type of boiler. It is set with an arch to ignite the incoming fuel and burn the volatile gases. This stoker is suitable for burning anthracite and bituminous coals and lignite. For burning anthracite and lignite a slight change is made in the grate-bar tops so that they will overlap in any position and thus prevent the fuel from sifting through. There are a number of installations where hog fuel has been burned very successfully in conjunction with coal. This is done by using an extension furnace and cutting a hole through the arch so that the hog fuel can be dropped through the arch and on the fuel bed.

The Wetzel stoker is somewhat similar to the Roney, the principal difference being in the form of grate used. Instead of being made up of bars extending across the furnace and rocking, the grate is made up of a series of bars extending from front to rear. These bars are ribbed to prevent sifting; the upper end of the grate is supported on a short rocker arm so that is has a slight forward-and-back motion, and the lower end on an arm placed at a somewhat different angle, so that the motion of the lower end of the grate is practically at right angles to the grate surface.

Ash

Most coal ash has a fireclay base with various kinds and amounts of foreign materials which act as fluxes, such as iron, lime, magnesia, and sodium and potassium oxides. An ash low in fluxes is desirable because it will be an ash of high fusing temperature and one which can be handled in a stoker more readily than an ash high in fluxes. It is also desirable when the maintenance of the stoker and boiler brickwork is considered, as small particles of ash impinge on the brickwork, and the iron, lime, etc., in the ash form an active flux for this firebrick at furnace temperatures.

The Design and Operation of Underfeed Stokers

By H. F. LAWRENCE,[1] PHILADELPHIA, PA.

This paper describes briefly the distinctive features of the single- and multiple-retort types of underfeed stokers, giving particulars regarding their operation and results that have been obtained. Emphasis is laid on the importance of proper adjustment of the secondary coal feed, to prevent clinker and ash depositing at the lower end of the retorts, and on draft control not too responsive to momentary variations in boiler conditions. Underfeed stokers are said to be particularly adapted to bituminous and semi-bituminous coals, and for carrying sudden overloading. Clinkers are a necessary result of the high temperatures secured, and different means for preventing their adhesion to the side walls are discussed. The relative merits of various fans are considered, and a table of setting heights is given.

UNDERFEED stokers are so designed that coal is fed from beneath the burning fuel. This is accomplished by feeding through retorts with adjustments so that the fuel bed is replenished throughout the length of the retort. The main feed from the coal hopper is accomplished with rams of fixed displacement so that the amount of fuel fed per stroke is a definite amount for a given coal, and therefore the amount fed per hour is accurately controlled by regulating the speed at which the rams are operated.

Single-Retort Stokers

The first development of this type was the single-retort underfeed stoker. This consists essentially of a horizontal retort, into which fuel is fed from the hopper and distributed throughout the length of the retort. Tuyeres are placed around the edge of the retort and through these air is supplied to the fuel under pressure from a fan. Dead plates or dump plates are placed on each side of the retort, from which the ash and refuse are removed. For wider furnaces, intermediate inclined movable grates or tuyeres are placed between the retorts and the dump plates. These serve the purpose of providing more grate surface and also of depositing the ash and refuse on the dump plate.

Single-retort underfeed stokers do not require large ashpits and ash tunnels below the boiler-room floor. They are cleaned of ash and refuse by dumping into shallow ashpits which are depressed slightly below the floor line, and withdrawing the ash and refuse through doors in the boiler front at floor level, or by withdrawing the ash from the dead plates through doors in the boiler front.

These stokers are also particularly adaptable to installations in which more than two boilers are placed in a battery, since side doors are not necessary to their operation. Boiler plants may then secure the advantages of the underfeed type of stoker without the expense of excavation and without being limited as regards arrangement of boilers.

Multiple-Retort Stokers

The multiple-retort stoker is a development of the single-retort and consists of a number of single retorts placed close together and inclined with the ash discharge at the rear. As the coal is burned the ash is formed on top of the fuel bed and is floated to the rear and deposited on dump plates or into crusher pits from which it is readily removed. The continuous ash discharge consists of rotary toothed crushers placed at the rear of the stoker and set low so that a large, deep pit is formed for receiving the ash and burning out the last of the combustible material.

The secondary coal feed, that is, the feed from the retort to the fuel bed, is obtained in various ways. The Taylor stoker uses additional rams similar to the coal-feeding ram, which are placed in the bottom of the retort. The retort inclination is such that the rams are reciprocated horizontally. The Westinghouse and the new Frederick stokers have a lesser inclination, and the secondary coal feeding is accomplished by large wedge-shaped castings placed at the bottom of the retort. These are reciprocated on an inclination corresponding to the slope of the bottom of the retort.

The Jones and Detroit stokers have similarly shaped retorts, and the secondary coal feed is obtained by small wedge-shaped pushers which are reciprocated horizontally in the bottom of the retort. The Riley stokers accomplish the secondary feeding by reciprocating the retort sides and the tuyeres. They also vary in the angle at which the tuyeres are placed—from horizontal in the case of the Detroit to 25 deg. in the Taylor stoker.

Tuyeres are placed between the retorts, and serve to convert the static head of air into velocity and direct the flow of air through the fuel bed. The tuyere designs naturally are different in each stoker.

All designs are for forced draft and cannot be operated at any appreciable capacity with natural draft. The air for combustion is circulated beneath the furnace parts and thereby cools these parts before being discharged through the fuel bed.

Operation of Underfeed Stokers

The operation of underfeed stokers is essentially as follows. The incandescent burning fuel is on top and is replenished throughout the entire retort length from beneath. As the coal emerges from the retort it is coked and spreads over the tuyeres, forming a homogeneous fuel bed across the entire furnace width. As the fuel approaches the surface the volatile matter is completely distilled off and the fuel completely coked. The surface consists of a layer of incandescent burning coke. The air for combustion is introduced near the point where the fuel emerges from the retort. As the volatile gases are liberated they are thoroughly mixed with air. As the mixture passes up through the fuel bed, higher-temperature zones are reached and complete combustion of the volatile gases takes place when they pass through the white-hot coke at the surface.

Smokeless combustion is obtained without the use of special mixing of ignition arches or special brickwork construction. As the fuel bed is replenished from beneath the surface, the burning incandescent coke which is on top is slowly moved toward the dump plates. As the ash is formed it is floated on the surface and is eventually deposited on the dump plates.

The control of the fuel bed is obtained by adjustments of the secondary coal-feeding arrangement. For good operation it is essential that the fuel bed be so controlled that the replenishing coal emerges from the retort through its entire length; the lesser amount being fed from the rear end of the retort.

With low-grade western coals more fuel must be discharged from the rear end of the retort than with the high-grade eastern fuels. In general, the greater the quantity of ash in the coal, the longer should be the stroke of the secondary fuel-feeding mechanism.

If insufficient coal is fed from the lower or rear end of the retort, the ash, instead of being carried on to the dump plates, is deposited at the lower end of the retorts, and as high fuel-bed temperatures are always obtained the ash is clinkered, and when deposited at this point it blocks the air discharge. After a short interval, fuel from the upper part of the retort, which is not coked, is deposited over this clinker formation and then avalanches on to the dump plates. With this condition of fuel bed it is impossible to secure good results or good operation. With proper strokes of the secondary coal-feeding mechanism this condition can be eliminated, as with the proper amount of coal being fed from this section of the retort the ash and clinker can never be deposited at this point. This is really the important adjustment to be made for various grades of coal, and it probably receives less attention from plant operators than any other variable. When properly adjusted the fuel bed is automatically maintained clean, and high rates of combustion can be obtained.

With the underfeed stoker properly adjusted, fresh fuel will be fed up throughout the full length of the retort. Green fuel moving upward with respect to the tuyeres tends to keep them buried, and consequently the ironwork is in the comparatively cool zone of the fuel bed. For this reason the maintenance is low on underfeed stokers.

With the underfeed system of combustion the excess air re-

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quired can be reduced to a minimum, which means that high fuel-bed temperatures are obtained. The fuel-bed temperature will probably always exceed the ash-fusion point of any of our coals. This means that clinker must be formed in order to secure the best combustion results.

Results Secured

These stokers are particularly adapted for burning bituminous and semi-bituminous coals. However, with only slight modifications lignites and coke breeze are also burned with excellent results.

With the thoroughly coked thick fuel beds carried, this apparatus is very quick in responding to load demands. Under running conditions the boiler capacity can easily be doubled almost instantaneously. From a banked-fire condition loads equivalent to 200 per cent of boiler rating and over can be picked up in a few minutes.

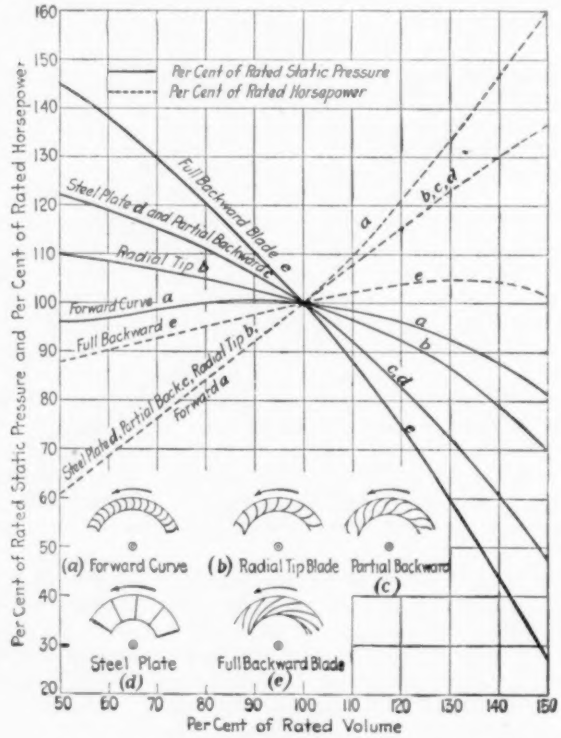

Fig. 3 Fan Characteristics at Constant Speeds

Many times the stoker manufacturer is handicapped by being forced to meet space limitations of the boilers. It is recommended that stokers be selected first, of the proper size and type to obtain the desired results, after which the boiler should be selected to meet the furnace requirements of the stoker.

Regulation

Automatic regulation is receiving a great deal of attention at the present time, and improved equipment has been developed which is giving good results. It is doubtful, however, whether regulating apparatus will ever be developed to the point where adjustments will not be required from time to time. These adjustments, it may be said, should only be made by an expert observer or fireman.

An ideal equipment would control all the variable elements in the proper proportion, thereby obtaining a constant steam pressure. It would, in addition to controlling the fuel, air supply, and drafts, be required to control the feedwater in proportion to the load.

Practically all regulating systems in use at the present time are controlled by variations in the steam pressure. The damper regulator is very sensitive to slight changes in steam pressure, and unless its action is retarded by some means, hunting will take place, causing rapid and wide variations in the air pressure. Much better fuel economy is obtained by eliminating the rapid fluctuations in air pressure. This is accomplished by damping the regulator so that a greater steam-pressure variation is required to operate it through its complete stroke.

The Jones fluid-operated rams are controlled by a Cole automatic valve for each cylinder. This valve is operated from a power source, usually driven from the fan or the fan engine. It is possible to obtain a number of different adjustments for the rate of turning this automatic valve, so that the rate of feeding fuel can be varied for each retort; in fact, all the retorts can be arranged to feed at one speed or at eight different speeds. Furthermore, each valve can be operated by a hand crank, so that the coal can be fed into the retort in very large quantities at any time it is required.

Fans

There are several types of fans used in stoker service, each of which has different characteristics.

The full-backward-curved fan with long blades, Fig. 3 (*e*), which is also a high-speed fan, has the best characteristics for stoker service. It has a very steep static-pressure curve, together with a comparatively flat horsepower curve, and has the additional characteristic that after reaching the maximum horsepower any further increase in volume due to reduction of static pressure, will reduce the horsepower required. The smallest-sized motors can be used safely on this type of fan, and it also has the highest efficiency.

For a fan operating against a constant resistance the power varies as the cube of the speed, the static pressure as the square

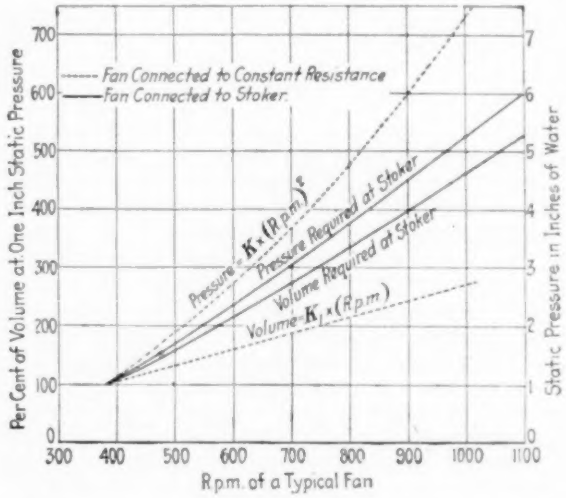

Fig. 4 Relation of Volume and Pressure of Air to Fan Speed

of the speed, and the volume directly as the speed. In underfeed-stoker practice, however, the resistance is not constant, so that the fans do not follow this law.

Fig. 4 shows in the dotted curves the volume and pressure characteristics in accordance with the constant-resistance law, while the full-line curves show the volume and pressure characteristics at the stoker connection. These curves have been plotted from data obtained in actual stoker tests.

Clinker Prevention

The most serious operating difficulties are caused by clinker adhesion to the side walls of the furnace. There are several successful methods for preventing this, the most popular one probably being that in which perforated firebrick blocks are located along the clinker line, through which the air is blown from the stoker air duct. Care must be used in locating these blocks so that no free air is discharged above the fuel bed.

Another method of preventing side-wall clinker uses special high side tuyeres through which air for combustion is discharged, these tuyeres extending high enough along the side walls to prevent the clinker adhesion to the brickwork.

Still another method which has been very successfully applied in a number of plants, is one in which cast-iron side-wall air boxes are used. These faces of the boxes toward the fuel bed are made of small overlapping ribbed plates. These plates are solid so that no air is discharged through them. Air enters one end of the box from the stoker air chamber and is discharged under the tuyeres from the other end of the box; this air circulation being sufficient to prevent burning of the plates and the ad-

TABLE 2 SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS EQUIPPED WITH STOKERS

(Min. = absolute minimum; P.M. = preferred minimum, i.e., the minimum heights recommended.)

Type of Boiler	Type of Stoker to be Installed													
	Multiple-Retort Underfeed		Single-Retort Underfeed				Side Overfeed		Front Overfeed		Chain Grates			
	Taylor, Westinghouse, Riley, Jones A-C		Type E		Jones Single-Retort		Murphy, Detroit		Roney		Natural Draft		Forced Draft	
	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.
WATER-TUBE:														
Horizontal	10′	12′	10′	12′	8′	10′	8′	11′	8′	10′	10′	12′	12′	14′
Inclined (Hor. M.D.)	7′	8′	6′	8′	6′	8′	5′	7′	6′	8′	6′	8′	7′	8′
Inclined (Vert. M.D.)	5′	6′	5′	6′	3′6″	5′	3′6″	5′	3′6″	5′	3′6″	5′	6′	8′
Vertical (Hor. M.D.)	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′
Vertical (Vert. M.D.)														
150-hp.	4′6″	5′	4′6″	5′	4′6″	5′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
250-hp.	5′6″	6′	5′6″	6′	5′6″	6′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
500-hp.	6′	6′6″	6′	6′6″	6′	6′6″	3′3″	....	3′6″	4′6″	4′1″	4′7″	6′	6′ 6″
HORIZONTAL RETURN TUBULAR:														
72-in.	8′	10′	8′	10′	7′	10′	7′	8′	6′	8′	7′	8′	8′	10′
84-in.	8′	10′	8′	10′	7′	10′	7′	9′	6′	8′	7′	8′	8′	10′

hesion of clinker. These boxes should not be less than 10 in. wide.

Carborundum bricks are satisfactory for this purpose with some coals. However, when the ash contains much iron, carborundum brick is rapidly eaten away.

TABLE 3 DEFINITIONS OF SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS

Type of Boiler	Setting Height
Water-tube, horizontal	Floor line to bottom of header above stoker
Water-tube, inclined	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Water-tube, vertical	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Horizontal return tubular	Floor line to under side of shell.

SETTING HEIGHTS

The Stoker Manufacturers' Association, in conjunction with the American Boiler Manufacturers' Association, have adopted minimum setting heights for all types of boilers which are given in Table 2. Setting heights for the different types of boilers are defined in Table 3.

A number of recent large boiler units have been set considerably higher than as specified in Table 2. The boilers of the new Hell Gate power station are set 21 ft., giving a furnace volume of $16^1/_2$ cu. ft. per sq. ft. of grate surface, or 390 cu. ft. of furnace volume per 1000 sq. ft. of boiler heating surface.

Frequently the combustion space required is stated as a function of the coal-burning capacity. This is misleading since it leaves out of consideration all conditions imposed by the arrangement of the boiler baffles and stoker in relation to one another.

It is desirable to keep the velocity of the rising gases in the furhace as low as possible, but a larger horizontal furnace section, with consequent large volume, may not necessarily do this.

Ample height of the boiler above the stoker should be secured in order that combustion of the gases may be completed before they enter the tubes.

High setting heights impose a more severe service upon the brickwork. Extreme care must be used in designing the furnace walls, so that they will stand not only the high furnace temperatures, but also the load. It is common practice at the present time to expose all of the first few rows of boiler tubes to the radiant heat from the fuel bed. This gives lower furnace temperature and greater life to the brickwork.

No arch construction or special brickwork is required in the application of underfeed stokers, and in fact it is preferable not to have arches. On account of the differences in the coefficients of expansion of different kinds of brick, however, only one kind should be used in the furnace.

Proper provision must be made for taking care of the expansion as the setting heats up. The brick should be carefully sized so that thin joints can be obtained. Each brick should be dipped in a thin fireclay wash and tapped into place with a wooden mallet until it touches the bricks next to it.

Walls should never be so constructed that they overhang or lean toward the furnace. Walls which slope outwardly from the furnace will give much longer service.

Discussion on Stokers at Fuels Session

ALEX. D. Bailey[1] submitted a written discussion in which he said that Mr. Marsh's statement that "modern steam turbines called for greater capacities from boilers" was not the whole story. Turbine development had been in a way parallel with boiler development, and along with the development of these two major pieces of equipment had been the coincident development of all plant equipment. So far as the boilers themselves were concerned, the demand for higher capacities had been occasioned by increased fuel costs and increased equipment costs, partly due to higher pressures and partly to economic conditions.

That the boiler proper had shown itself capable of taking care of these higher rates of heat absorption without materially decreasing its efficiency was evidenced by the very marked development of stokers and other coal-burning equipment during the past few years. The chain grate, which was probably one of the oldest forms of mechanical stoker known, had had to fulfill its part in this development in order to justify its existence, and the development of the forced-draft chain grate was the result.

Just as the natural-draft chain-grate stoker had made possible the use of coals which were unsuited to existing types of stokers which were consequently cheap, so the forced-draft chain grate had made available not only low-grade fuels, but also coke breeze and smaller sizes of anthracite, which had not been previously considered suitable for power production. This economic saving alone justified the improvement in chain grates.

John M. Drabelle[2] wrote that in the Central West, particularly in Iowa, there was a rather peculiar type of fuel available, namely, one low in heat value (8500 to 9000 B.t.u. per lb. as screenings) and having a high ash content (20 to 35 per cent), the ash being easily fusible. To burn this it was necessary to have an undisturbed fuel bed, a large furnace volume, and a high ignition rate. The chain-grate stoker, judging from several years of actual operating experience, was the only stoker successful in handling this type of fuel.

In judging stoker performance it was necessary to bear in mind that it was the total cost per 1000 lb. of water evaporated and not percentage efficiency that must be dealt with. The maintenance problem was a serious and important one, also the amount of operating labor required and the item of investment, the latter in turn determining fixed charges.

The ideal chain-grate stoker, Mr. Drabelle believed, would be a combined natural-draft and forced-draft stoker operating under

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[2] Mechanical engineer, Iowa Railway & Light Co., Cedar Rapids, Iowa. Mem. Am.Soc.M.E.

the normal operating conditions of the station on natural draft and over the peak load with forced draft, thereby reducing the amount of auxiliary power required to the absolute minimum, and resulting in a lower cost per 1000 lb. of water evaporated.

J. R. Fortune[3] submitted a written discussion in which he said that there ought to be some way of designating stokers other than by the terms "underfeed" and "overfeed." There was but one type of stoker that, in his opinion, could truly be described as overfed, and that was the sprinkling stoker, which was not very well known in this country but which was quite commonly used abroad. This was the only stoker in which the fuel was fed on top of the burning fire. The fuel in the stokers of the Murphy, Roney, and chain-grate types was always, in effect, underfed. In other words, there was a layer of fuel unignited close to the grate bars near the stoker hopper, and this was overlaid with fuel which was burning almost all the way to the feed opening of the stoker. The unignited fuel close to the grate bar might extend halfway down the grate.

A. H. Blackburn[4] wrote that in drawing attention to the many types of underfeed stokers Mr. Lawrence had omitted to mention the lateral-retort stoker brought out by The Under-Feed Stoker Company of America during the present year. The novel feature of this stoker was that it fed the coal in through a main retort extending from the front wall of the furnace to the bridge wall, with lateral retorts branching off the main or central retort at right angles. The front and back walls of the furnace were protected by high air-cooled tuyeres, the stokers having been designed for working continuously around 200 per cent boiler rating. The design of the stoker enabled it to be installed without a basement and under low-set boilers that might be already installed.

Walter N. Polakov[5] in a written discussion said that, quite apart from the excellence of design and construction of its mechanism, and altogether independently of its adaptability to fuel used, the success or failure of a stoker depended largely upon the mode of its use.

The Stoker Not an Automatic Device

Sometimes it was claimed that a mechanical stoker was an automatic device and that by virtue of its so-called automatic action the plant owner could "forget his power plant." A stoker, however, was automatic only in so far as it replaced a certain amount of physical exertion by the substitution of mechanical power. For this reason alone the stoker attendant was no longer interested in how he could spare himself the pain of shoveling unnecessary coal into a furnace, and unless he had other stimuli he would let the stoker feed as much coal as it could and make as little steam as it might. Again, when supplementing a mechanical stoker automatic regulating devices were introduced, they as a rule controlled only one or few detached factors, but never the operation as a whole. Worse yet, in many cases these automatic controllers operated either a little behind time or made adjustments of conditions by steps, the consequence being that losses were increased coming and going. Even with oil firing he had on record cases where automatic regulators of merit had to be discontinued and manual control introduced in order to improve the evaporating efficiency.

The foregoing was neither theory nor generalization, but a summary of facts which had come under his observation during the last twenty years.

Wm. R. Roney,[6] who in recognition of his pioneer work in stoker design and construction had been asked by Chairman Breckenridge to share the platform and open the oral discussion, spoke briefly regarding troubles encountered in stoker operation, and said it was his experience that the human element was the most important factor in the satisfactory handling of such equipment.

David Moffat Myers,[7] agreed with Mr. Roney as to the importance of the human element. He further called attention to the fact that nothing had been said in the papers regarding marine applications of stokers. Here was a wonderful field for effecting economy; less coal would be used, thus leaving more space for carrying revenue-producing cargo. He was desirous of learning the attitude of stoker manufacturers toward automatic regulation. He thought that in specifying heights of boiler settings the figures should be related to the capacity rating expected from the boilers.

Later in the discussion Mr. Myers said that during the war, in the course of an investigation of the possibilities of stokers and Scotch boilers, he had come across a stoker that had been used extensively and successfully on locomotives. Locomotive practice was similar in some respects to marine practice, both having to deal with very cramped fireboxes and very small combustion space. The stoker in question involved also the use of a screw conveyor which brought the coal from the tender to a point at the footboard of the locomotive. From that point screws inclined at about 60 deg. carried the coal up to two points on either side of the fireboard and above it, from which points it was distributed over the fire by steam jets. In case of a breakdown on board ship, it would not be necessary to discard such a stoker, because it could be fired by hand without any difficulty.

Furnace Volume Essential for Good Design

J. E. Woodwell[8] said that one of the principal essentials of stoker design was furnace volume, for in running on high ratings at peak load it cost money to replace furnace linings, brickwork, etc., and to have boilers out of commission while such repairs were being made. Accordingly, in his last central-station design, he had installed stoker capacity 15 per cent in excess of anything that had been done in the Hell Gate and other new stations, simply as a reserve against furnace repairs and so that the boilers would be in service 100 per cent of the time.

As to automatic control, he did not agree with Mr. Polakov. Manual control could never equal automatic control under proper supervision.

Theodore Maynz[9] called attention to the fact that in operating chain-grate stokers it was necessary to watch the carbon in the ash. With some coals, running with 35 to 40 per cent air would give good carbon, but with others the air would have to be raised to 60 or 70 per cent before the total loss was a minimum.

One of the most important things in operating forced-draft and natural-draft chain-grate stokers was to have uniform coal. This was difficult, for even when it was mixed in advance, by the time it got to the coal hoppers it was segregated, the coarse going through the center and down the sides while the fine coal packed about a foot from the wall to about within a foot of the center. His company had had some success in obviating this by employing tilting and split gates in order to maintain a more even fuel bed.

The rear end of the stoker should be sealed either by banking coal against the water back or by means of ashes between the lower portion of the grate and the ash pit. With a forced-draft chain-grate stoker, the dirt coming out from the front made a boiler room almost uninhabitable, especially when there was, say, only about 0.05 in. draft in the furnace. He believed with Mr. Polakov that instruments were absolutely necessary, no matter how small the plant, and that the men appreciated them.

Edwin Lundgren,[10] replying to the questions propounded by Mr. Myers, said that one reason why stokers had not been applied extensively in marine practice was that while fuel obtained in one port might burn satisfactorily, the next fuel bunkered might give a great deal of trouble.

Another difficulty was the limited space between the tubes of the boiler and the bottom of the ship, which made it necessary to install a horizontal type of stoker. The company with which he was connected had applied that type of stoker to several ships in Europe and had reported in most cases very successful operation.

As to automatic regulation, speaking as a stoker manufacturer he would say that there were so many varying factors that must be compensated for that it could not be other than unsatisfactory. It had been his personal experience that the best control was that which an intelligent fireman would give when provided with proper

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[4] Chief engineer, Under-Feed Stoker Co. of America, Worcester, Mass. Mem. Am.Soc.M E.

[5] Consulting engineer, New York, N. Y. Mem. Am.Soc.M.E.

[6] New York, N. Y. Mem. Am.Soc.M.E.

[7] Consulting engineer, Griggs & Myers, New York, N. Y. Mem. Am.Soc.M.E.

[8] Consulting engineer, New York, N. Y. Mem. Am.Soc.M.E.

[9] Test engineer, Cleveland Elec. Illuminating Co., Cleveland, Ohio. Mem. Am.Soc.M.E.

[10] Vice-president and chief engineer, Frederick Engineering Co., Frederick Md. Assoc-Mem. Am.Soc.M.E.

instruments for his guidance and means whereby he could easily adjust the factors that varied.

Albert A. Cary[11] called attention to a previous statment he had made to the effect that when a fuel carrying combustible gaseous matter was charged upon a hot fire bed, the first thing that happened was the distilling of the gaseous matter, this gas going up into the combustion chamber and being burned there. It was only the coke or fixed carbon that remained behind that was really consumed on the grate. Therefore, if it was desired to specify the capacity of a stoker by the rate of combustion, the latter should be expressed in pounds of fixed carbon burned per square foot of grate area per hour, not in pounds of fuel. Rousting and hand manipulation of the underfeed stoker was something that needed to be done away with in order to get the best results.

Alfred B. Carhart[12] said that he was very strongly inclined toward regulation by intelligent operators as against automatic control beyond the reach of the operator. Automatic control gave an average, but only through the intelligent operator could there be obtained adjustment to varying conditions which would be in control of the actual results of the moment, instead of historical records afterward to show what mistakes had been made.

C. G. Spencer[13] called attention to the fact that the coal now supplied to the East had entirely different characteristics from the fuels for which stations in that section had been designed. There was no reason to believe that the industrial war in the coal fields was ended, and that being the case, the pressing need was for a stoker that would handle effectively a variety of coals.

H. C. Heaton,[14] discussing the stratification of coal in bunkers, said that unless bunkers were properly designed the coal would tend to pile up and stick together on the sides of the bunkers, with the result that it would avalanche and supply successively different sizes to the grate. He had seen coals that would stand almost vertically on the sides of the bunker, which of course, was impossible to overcome. He believed that the best way to handle coal out of the bunker to the grate was with a spout that would swing and spread the fuel uniformly over the grate.

Smoke Abatement

O. P. Hood,[15] at the instance of Chairman Breckenridge, spoke briefly of the chaotic situation regarding smoke abatement in the various sections of the country. Most of the smoke ordinances, he said, were largely concerned with matters of administration. There was need for a simple statement of the technical requirements —what kind of smoke could be allowed, and for how long, etc.—and such a statement was now being drafted by a committee fathered by the Fuels Division of the Society and having in its membership representatives of the Heating and Ventilating Engineers, the Stoker Manufacturers' Association, railroads and other interested bodies. The matter of administration, it was proposed, should be left to each community for settlement. Mr. Hood, it should be stated, is chairman of the committee in question.

Henry M. Burke[16] said that as the operator of a 5000-hp. industrial plant he had found that the automatic control of the entire plant was impossible from the standpoint of efficiency, as was also control by manual means where a bonus scheme of payment obtained, because in that case the firemen were anxious to do more work and took care of too many operations to operate the plant most efficiently. He had therefore worked out standards according to the loads carried by the plant and had sectionalized the control, taking up the peak loads with manual control and carrying along the regular load by the automatic control. The plan had worked satisfactorily, not only on the stoker boilers but also on the boilers fired with fuel oil.

J. B. Crane[17] said that in his opinion the best plan was to set as many boilers in a plant as possible to carry a steady load and employ automatic regulation to keep steam pressures up to the remainder. As to furnace volume, his company had started in 1916 to put in boilers with $4^1/_2$ cu. ft. per rated hp., and the results had fully warranted that action. It was known now that instead of the melting point of the brick being the factor, it was the point at which it began to compress. Consequently, if combustion chambers were designed so that the load on the hot zone would not be more than 25 lb. per sq. in., were inclined away from the grate upward, and were provided with some means for overcoming the slight tendency of the brickwork to fall into the center of the combustion chamber, he believed that no further trouble would be experienced with combustion chambers, no matter how heavy the loads that were carried on the boilers.

Jos. J. Nelis,[18] speaking of the problems of marine men, said that the sea had not attracted the technical man as yet, and until it did, he did not think there would be a very general adoption of improved machinery.

Another matter to consider was the space available. Tests recently made by the Bureau of Mines and the Shipping Board had shown that with practically one-quarter of the volume used ashore, the Scotch boiler gave over 80 per cent efficiency, so that this boiler had been adapted for marine service because it had been found to be the best boiler; but it was passing, not because it was not the best boiler, but because pressures were coming up. Stokers had been tried on the Scotch boiler, principally the underfeed types. They would not get rid of the clinkers, however, so that they had been finally abandoned.

The marine man had one thing in his favor that the shore man did not have, namely, an absolutely steady load factor. It was therefore possible to design for a marine power plant closely, and to get higher efficiency than in the case of a shore plant with fluctuating load. There was a chance now to install stokers on ships, provided a low, flat boiler to get the furnace volume became available.

Fewer Coal Sizes Suggested

Lester C. Bosler,[19] said that anthracite coal operators thought that there should be a reduction in the number of sizes. They would like to eliminate the rice and two sizes of barley now produced and combine them into a size called bird's-eye, which would mean a size through $^1/_4$ in. and over $^1/_{16}$ in., and preferably through $^1/_4$ in. and over $^1/_{32}$ in.

M. Alpern,[20] representing the Stoker Manufacturer's Association, spoke briefly of its work in correcting evils that had cropped up, in improving the design of all stokers, and in creating a wider market for such equipment.

Chairman Breckenridge said that he did not subscribe to the idea that the furnace volume was a function of the horsepower of the boiler. He believed that it was a function of two variables: the rate at which coal was burned in the furnace and the volatile content of the coal that was being burned. In other words, the amount of volatile combustible material leaving the grate was the determining factor of furnace volume.

R. Sanford Riley,[21] in reply to a question raised by Mr. Myers in regard to fusion on the surface of the underfeed stoker because of the fuel working upward to the higher-temperature zone, said that clinkers were the logical result of thoroughly burning out ash if the ash had the proper chemical elements. As to the troubles encountered from these clinkers, which were inherent in certain kinds of coal in general, in underfeed stokers he desired to avoid arches because of the reverberatory action under them, which raised the temperature and made the clinkers still more liquid, causing them to run and make more trouble. In general this led up to the utilization of the maximum amount of radiation, using radiation as the means of transferring heat from the fuel bed to the boiler. By making this transfer as direct as possible there would result a cooler fuel bed, less trouble with brickwork, higher efficiency, and less trouble with clinkers.

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[12] Precision Instrument Co., Inc., New York, N. Y. Mem. Am.Soc.M.E.

[13] Mechanical engineer, McClellan & Junkersfeld, New York, N. Y. Mem. Am.Soc.M.E.

[14] Mechanical engineer, Sargent & Lundy, Chicago, Ill. Mem. Am.Soc. M.E.

[15] Chief mechanical engineer, Bureau of Mines, Washington, D. C. Mem. Am.Soc.M.E.

[16] Mechanical engineer, Mt. Hope Finishing Co., North Dighton, Mass. Mem. Am.Soc.M.E.

[17] Engineer, The George T. Ladd Co., Pittsburgh, Pa. Mem. Am.Soc.M.E.

[18] Manager Marine Department, Power Specialty Company, New York, N. Y. Mem. Am.Soc.M.E.

[19] Mechanical engineer, Madeira, Hill & Co., Philadelphia, Pa. Mem. Am.Soc.M.E.

[20] President, American Engineering Co., Philadelphia, Pa. Mem. Am. Soc.M.E.

[21] President, Sanford Riley Stoker Co., Worcester, Mass. Mem. Am. Soc.M.E.

As to automatic regulation, the difficulty heretofore had been in getting operators with intelligence enough to regulate the fire directly, that is, the various drafts and the feed of the coal. It took a little higher grade of intelligence to regulate a regulator than it did to regulate the drafts and the coal feed directly; but he believed that before long regulators would be much more generally used, which was equivalent to saying that the grade of fire-room operators was being raised.

Regarding setting heights, it was not claimed that the specifications adopted were perfect, but it was certainly a great advantage to all to have some standard established by which some of the most serious mistakes made in the past might be avoided.

W. J. Wohlenberg,[22] discussing automatic control, said that in the case of parallel operation of a number of forced-draft stoker-fired boilers, the device first to respond to the load would be one that would be actuated by a change in pressure. That device would operate a throttle valve or an electric control governing the fan used to drive air through the fuel bed. If a similar change was desired in all parts of the equipment, every device and fan would have to have similar characteristics and then the right condition would be obtained only provided the same kind of fuel bed with the same kind of fuel was under every boiler. That, it would be seen, made parallel operation automatically very difficult.

W. G. Freer[23] said that he had spent 20 years at sea and knew what had to be accomplished in order to operate stokers on shipboard. The stoker being installed in nearly all the locomotives built by his company, he believed, could be adapted for such service. It distributed the coal evenly over the fire by means of a pair of mechanically actuated firing shovels.

J. C. Percy,[24] thought that stoker manufacturers could do away with much of the trouble experienced by their customers if they would manage in some way to furnish proper instruction to the men who were to operate their equipment.

Closures

T. A. Marsh, in closing, said that the real thing in efficiency was the cheap production of steam. Sometimes it was possible by burning a cheaper coal with low efficiency to make cheaper steam. He agreed with Mr. Riley, that automatic control was coming, for he knew of a number of installations working very successfully under such regulation in the West.

Answering Mr. Maynz on the tightness of forced-draft stokers, he would say that there were types on the market today that were very tight and would not blow out. He took exception to Mr. Cary's statement that on the grate we burned fixed carbon. We did not. It rested on the grate until it was thoroughly burned; but the only thing that we could possibly burn was gas. As to Mr. Cary's question regarding caking coals, he would say that they were not suitable for chain grates, and chain-grate manufacturers were not attempting to burn them today.

H. F. Lawrence, in summing up the comments on his paper, said, referring to Mr. Polakov's discussion, that the mechanical stoker was more than a coal-feeding mechanism. In addition to putting the coal into the furnace, it had to deposit the ash into some locality from which it could be easily removed, and also furnish the air at such places and velocities and directions as to accomplish the burning of the fuel in the best manner.

As to Mr. Myers' references to the clinker on top, the under feed stoker of course formed its ash on top. It was the feeding of the coal from the retort that flooded the ash on the fuel bed. The coal, in addition to rising up, was pushed forward so that the ash was carried forward toward the grate wall with the fuel. There was a comparatively small amount of ash, and the main feature to avoid trouble of this kind was to get the secondary coal-feeding mechanism—that which controlled the issuance of the coal from the retort—in such relation to the particular fuel and the amount that it would carry the clinker on beyond the end of the retort before depositing it.

With reference to burning different coals, the underfeed stoker was built with adjustments, the principal one being this control of the coal from the retorts, which was what made it possible to burn a wide variety of coals on the underfeed stoker.

As regarded cinders, it could be said that the higher setting heights were reducing them, and that the lower air pressures and lower velocities of air which would come as designs were improved, would also reduce them.

With reference to slag on the tubes, they were reduced by the high settings. With some fuels this slag was much worse than with others, and provision should always be made in the boiler setting to get at it and remove it.

[22] Asst. professor of mechanical engineering, Sheffield Scientific School Yale University, New Haven, Conn. Mem. Am.Soc.M.E.

[23] Power engineer, American Locomotive Co., Schenectady, N. Y. Mem. Am.Soc.M.E.

[24] Mechanical superintendent, Julius Kayser & Co., Brooklyn, N. Y. Mem. Am.Soc.M.E.

Improving Power-Plant Efficiency

There are three ways of improving power-plant efficiency—maintaining the efficiency of the operating cycle, selecting the proper equipment, and improving the equipment by changes in design. Although in coal-burning plants over-all thermal efficiencies of about twenty per cent have been obtained under favorable conditions, even in the largest plants the average for a year is far below this figure. Fifteen per cent is about the best that the average large station is doing, with many plants, having ratings for twenty thousand to thirty thousand kilowatts capacity, operating at ten per cent or less. Instead of producing a kilowatt-hour on seventeen or eighteen thousand British thermal units, the average figure will be from twenty-three thousand to over thirty thousand.

There are many conditions in plant operation that tend to reduce the average over-all efficiency; some of them are controllable and others are not so readily handled. Load factor undoubtedly has an effect, but cases are on record where, in plants of considerable difference in size, the smaller plant operating at about forty per cent and a larger one at sixty per cent load factor, the smaller plant showed thirty per cent less coal consumption per unit output than the larger station. Even though these conditions may exist, taking two plants that are alike as to equipment, if both are operated with equal proficiency, the station with the highest load factor will develop the highest over-all average efficiency.

For years it has been possible to obtain an over-all boiler-and-furnace efficiency of over eighty per cent with large stoker-fired boilers without the use of economizers, yet the average in many of the large plants is down around sixty-five per cent or less. There are a few exceptions to these figures where efficiencies up to about seventy-seven per cent have been obtained without the use of economizers. The maintenance of equipment has a marked effect on over-all efficiency and is very largely under the control of the operating force.

The wide difference in average operating efficiencies of two plants under similar conditions can be attributed to operating methods and the selection of the kind and size of equipment to serve the load. When selecting equipment, it is not always possible to obtain the arrangement that will give the highest over-all efficiency, or engineers have not felt justified in doing so. All electric drives for the auxiliaries and bleeder turbines for feed-water heating will give a higher over-all economy than using steam-driven auxiliaries. The possibilities of the station going dead have deterred power-plant engineers from taking full advantage of benefits to be obtained from this arrangement. Then again there is the matter of cost. Will the installation of equipment that will reduce the coal consumption reduce the kilowatt-hour cost at the switchboard?

Present indications are that in the near future no radical improvement in efficiency may be looked for in the design of power-plant apparatus, although the substitution of a regenerative cycle for the Rankine and higher steam pressures offer possibilities that are encouraging.

While power-plant engineers are waiting for the higher economy to be obtained from new designs, the present differences between the average over-all plant efficiency and that which can be obtained with present design of apparatus offers a fruitful field for careful study and improvement. (*Power*, Dec. 12, 1922.)

Tests of a Large Type W Stirling Boiler

Particulars Regarding Extensive Tests Recently Conducted by The Detroit Edison Company, in Which Various Baffle Arrangements and Different Grades of Coal Were Used

By PAUL W. THOMPSON,[1] DETROIT, MICH.

This paper deals with extensive tests conducted during 1921 on a large Type "W" Stirling boiler at the Connors Creek power house of The Detroit Edison Company. Four different arrangements of the boiler baffling were employed and the results obtained with each are shown. Separate tests were made using four different grades of coal in order to determine which was most suitable. Several operating tests were made to obtain data on different methods of banking, the effect on the temperature of flue gas of varying the time interval between the blowing of flues, and different methods of operating boilers during the low-load period at night.

From the results of the tests with different baffle arrangements, seventeen of these large boilers have been rebaffled with a resulting improvement in boiler-plant efficiency and an increase in the degree of superheat of the steam. Additional improvement is expected as more boilers are rebaffled. From the data and results of these tests, the Babcock & Wilcox Company, working in conjunction with The Detroit Edison Company, have developed a new design of this type of boiler. Four boilers of the new design have been installed in the Marysville power house of The Detroit Edison Company, but economy results on the installation are not yet available.

SINCE the original installation of the large Type W Stirling boilers by The Detroit Edison Company in 1911, many improvements have been made and much experience has been gained in regard to bettering the overall performance of these steam-generating units. The results of the first tests conducted on this type of boiler were presented before the Society by Dr. D. S. Jacobus in 1911. Several tests have been conducted since that time with other objects in view than to obtain accurately the efficiency, but none involving the weighing of water and coal.

Several years of experience in operating these boilers had brought about many improvements, both in methods and in design of auxiliary equipment, yet it was felt that there still remained further opportunities for improving the operating performance. The determination of means for obtaining improved performance comprised the main purpose of these tests.

Eight series comprising fifty constant-rating tests were made, during which four different grades of coal were burned and four different arrangements of the boiler baffling tried out. Table 1 gives general data and dimensions of the equipment and Table 2 the names and sources of the coals, together with the quantities burned. Figs. 1, 2, 3, and 4 show respectively the four baffle arrangements: namely, the original baffle, the "A" baffle, the "B" baffle, and the "C" baffle.

Some idea of the magnitude of the test may be gained from the fact that the total coal weighed to the stokers during the entire test was 12,137 tons, and the total water fed to the boilers 101,200 tons. During the highest-rating test the coal consumption averaged 22,550 lb. per hr. A complete record was maintained of the weights of coal and water during periods between tests, including seven firing-up and burning-out periods, from which data an overall efficiency for the entire period up to and including test No. 76 was computed and found to be 77.9 per cent.

The tests were commenced April 7, 1921, and completed August 27, 1921. The full number of observations were taken until August 6 only, after which date operating tests were conducted for the purpose of determining the effects of blowing flues at various intervals of time and also to obtain data on the amount of coal required for different kinds of banks. These tests were conducted with a reduced force, taking only the most essential observations. During the period from April 7 to August 6 the services of 57 observers working on three eight-hour shifts were required, besides those engaged in analyzing coal and ash, and others conducting special investigations and checking methods.

Facilities were provided for analyzing the flue gases at points as close as possible to the sampling points. There were two sampling groups on each side of the boiler, one at the bottom of the superheater pass and one at the damper. In addition to these points at which gas samples were taken and analyzed in Orsats, two different types of automatic flue-gas recorders were installed, one drawing samples from four points on each side at the damper and recording an analysis of an average of these samples, and another from one point on each side at the bottom of the superheater pass.

The points at which the pass temperatures were measured are

TABLE 1 GENERAL DATA AND DIMENSIONS OF EQUIPMENT

Boiler:

Type W Stirling, manufactured by Babcock & Wilcox Company. Total number of tubes, 1564; diameter, $3^1/_4$ in.; 9 gage. Net effective heating surface, 23,654 sq. ft. Installed and first in operation October 25, 1920.

Superheater:

Twin B. &. W., U-tube. Two superheaters having 102 tubes each. Tubes 8 gage, 2 in. in diameter; developed length, 24 ft. $11^5/_8$ in. Total heating surface, 2996 sq. ft.

Stoker:

Underfeed stoker manufactured by American Engineering Company, Philadelphia, Pa. Two 13-retort, 2-ram stokers; total width, 22 ft. $10^1/_2$ in.; effective length (both stokers), 12 ft. 5 in. (ashpit not considered in giving effective length). Projected grate area, 284 sq. ft. Width of ashpit, 3 ft. 11 in. Ratio of saturated heating surface to grate area, 83.4 to 1. Drive: variable-speed d.c. motors. Clinker grinders: independent drive by d.c. motors.

Setting:

Height of mud drums above floor	15 ft. 9 in.
Height from grate to top of combustion chamber	33 ft.
Width of combustion chamber	26 ft. 2 in.
Length of combustion chamber over grate	16 ft. 4 in.
Total volume computed above grate	8705 cu. ft.

Forced-Draft Fan:

Double conoidal blower manufactured by Buffalo Forge Co. Capacity, 74,000 cu. ft. at 6.5 in. water pressure. Driven by variable-speed d.c. motors.

Stack:

Height above center of grate	323 ft. 6 in.
Inside diameter of stack at top	15 ft. 9 in.

Dampers at boiler are motor-operated.

TABLE 2 COAL DATA

(1) Name of Coal	(2) Location of Mine	(3) Tests	(4) Coal burned during tests of column (3), lb.	(5) Duration in hours of tests of column (3)	(6) Heating value of coal, B.t.u. per lb.
Shipper "A"	Harlan, Ky.	Nos. 3 to 18	6,785,888	613	—
Shipper "A"	Harlan, Ky.	Nos. 40 to 43	1,744,337	128	12,510
Shipper "A"	Harlan, Ky.	Nos. 60 to 66	2,857,053	242	—
Shipper "A"	Harlan, Ky.	Nos. 70 to 76	3,271,959	266	—
Shipper "B"	Mingo, W. Va.	Nos. 20 to 24	2,304,682	196	13,280
Shipper "C"	Kanawha, W. Va.	Nos. 18–30 to 33	1,668,998	143	12,320
Shipper "D"	Logan, W. Va.	Nos. 50 to 54	1,937,176	154	12,200

Averages for Whole Test:

Coal per hr., lb	11,780
Water per hr., lb	98,600
Per cent rating	145.6
Apparent evaporation	8.37
Equivalent evaporation	10.10
Per cent efficiency	77.9
Weighed refuse in per cent of coal burned	11.30
Computed refuse in per cent of coal burned	13.92
Loss to stack in per cent of refuse	18.8

shown on Figs. 1, 2, 3, and 4. All points on the west side have even numbers and those on the east side, odd numbers. Each location except 15 and 16 represents two couples: one placed in the center *C*, the other placed in the south half *S* if it is on the east side, and in the north half *N* if on the west side. The furnace

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temperature was obtained at point F at the north and south ends of the furnace by focusing an optical pyrometer on the closed end of a carborundum tube, the tube being of ordinary test-tube shape and projecting about 30 in. into the furnace. In addition to the observations taken at the points mentioned above, a recording potentiometer was used for recording the temperatures at the two dampers separately, each record being an average of five equally spaced points on either side.

In addition to the four operating draft gages regularly provided

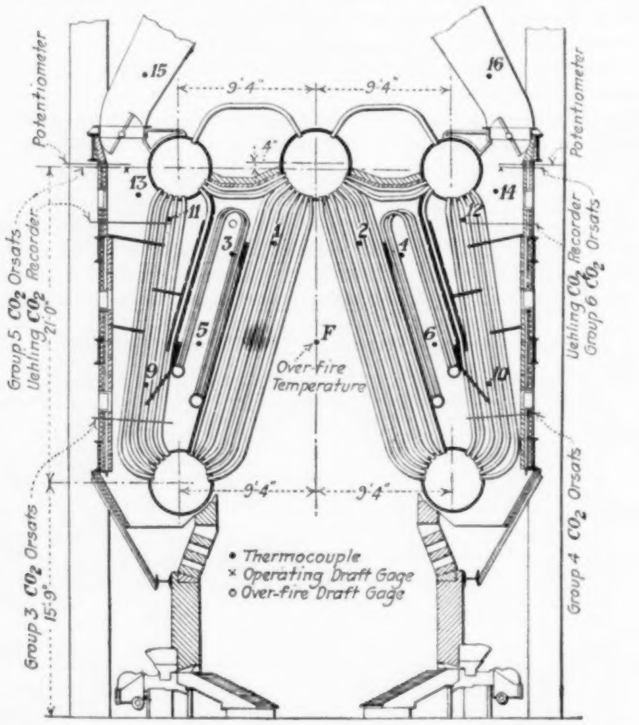

Fig. 1 Original Baffle Arrangement in the Type W Stirling Boiler Tested

on the control board, the drafts were measured at points as close as possible to where thermocouples were installed.

The quantity of air supplied to the air chamber beneath the stoker was measured by a Thomas air meter installed on the suction side of the blower.

All testing equipment was installed and the tests were run under the direct supervision of the author, assisted by Mr. A. K. Bak,

TABLE 3 COMPARISON OF COAL ANALYSES

(Analyses are for dry coal and are made on duplicate samples. Samples Nos. 106, 116 and 126 are Shipper "A" coal; sample No. 138, Shipper "B" coal)

Test No.	Sample No.	Analysis made by	Proximate Analysis				Ultimate Analysis					
			Fixed carbon	Volatile matter	Ash	B.t.u.	C	H_2	O_2	N_2	S_2	Ash
4	106	D	55.30	33.50	11.20	13133[1]	73.55	4.44	8.76	1.30	0.75	11.20
		S	54.14	34.93	10.93	13297	70.57	5.15	10.93	1.38	1.04	10.93
		P	54.96	34.40	10.64	13062	73.67	4.72	8.44	1.37	1.16	10.64
9	116	D	55.15	34.55	10.30	13365[1]	74.59	4.82	7.85	1.51	0.90	10.30
		S	53.88	36.08	10.04	13284	74.91	5.13	7.83	1.14	0.98	10.04
		P	54.38	35.34	10.28	13150	74.10	4.98	8.09	1.44	1.11	10.28
14	126	D	54.90	34.85	10.25	13352[1]	75.12	4.72	7.45	1.32	1.14	10.25
		S	53.40	35.87	10.73	13298	71.94	5.30	9.26	1.44	1.33	10.73
		P	55.28	34.03	10.69	13146	72.48	4.98	9.10	1.43	1.32	10.69
24	138	D	58.75	33.50	7.75	13927[1]	75.83	5.08	9.06	1.25	1.03	7.75
		S	55.54	35.65	8.81	13520	75.88	5.90	7.01	1.26	1.14	8.81
		P	57.11	33.93	8.96	13584	77.63	5.19	5.56	1.41	1.25	8.96

[1] Values used in computations. D, The Detroit Edison Co.; S, Solvay Process Co.; P, Pittsburgh Testing Laboratory.

technical engineer of the Connors Creek station. Coal and water-weighing equipment was installed by the Construction Engineering Bureau of The Detroit Edison Company. The Thomas air meter and thermocouples were made and installed by the Research Department under the personal supervision of Mr. W. A. Carter. The author wishes to express his appreciation to Mr. J. W. Parker and Mr. C. F. Hirshfeld of The Detroit Edison Company, and to Dr. D. S. Jacobus of the Babcock and Wilcox Company for their valuable suggestions and criticisms, and to all those who in any way contributed to make the test a success.

Description of Tests

The eight series of tests were made up of 50 constant-rating tests, each series being conducted under different conditions. The first series (tests Nos. 2 to 10) was for the purpose of obtaining the efficiency before making any changes in the boiler or its auxiliary equipment. Shipper "A" coal was used since a regular and uniform

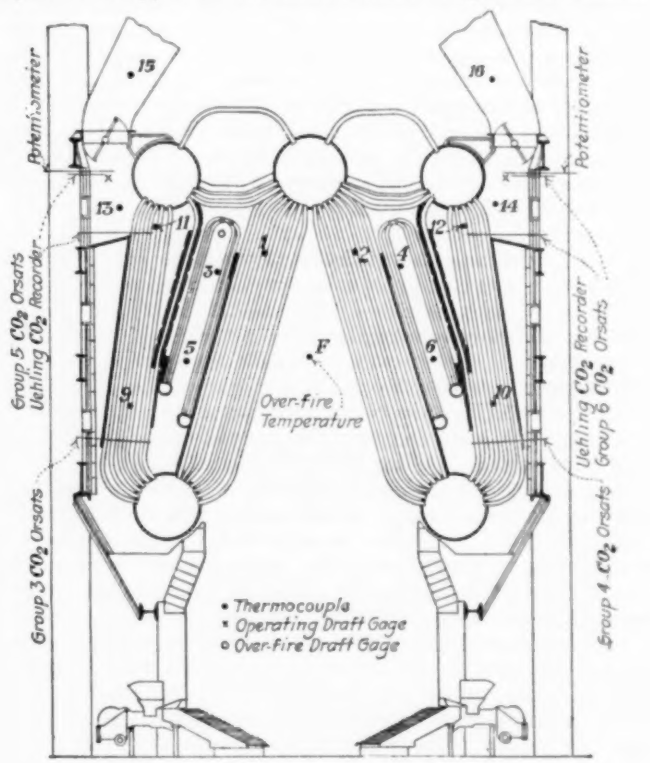

Fig. 2 "A" Baffle Arrangement

supply could be counted upon, and its quality was about an average of the many kinds being received at that time.

At the time the tests were commenced the boiler had been in regular service for six months, and it was decided to ascertain how much the efficiency was impaired by the soot which gradually collects on the tubes and is not removed by the soot blowers. To this end the first series of tests was conducted without specially cleaning the boiler. Then the boiler was given a thorough washing on its exterior surface and a second series of tests (Nos. 11 to 18) was run, also using Shipper "A" coal.

When Dr. Jacobus made his tests on this type of boiler in 1911 he used Red Jacket coal, so for the purpose of comparing results obtained in 1911 with those obtainable now, a series of tests was made (Nos. 20 to 24) using Shipper "B" coal, which, in quality, was as close an approximation to the coal used by Dr. Jacobus as could be obtained. This coal, however, was of poorer quality having a lower heating value and higher moisture and ash than the 1911 variety.

Tests Nos. 30 to 33 were made with Shipper "C" coal to determine its burning characteristics and adaptability for use on this type of stoker. The boiler baffling was then changed to conform to that shown in Fig. 2, called "A" baffle arrangement, and a fifth series of tests (Nos. 40

to 43) was made using Shipper "A" coal. Another series of tests using Shipper "D" coal was also made with this same baffle arrangement (tests Nos. 50 to 54) in order to obtain the burning characteristics and adaptability for use of this coal.

After test No. 54 the baffle was again changed to the "B" arrangement shown in Fig. 3, and a seventh series of tests (Nos. 60 to 66) was conducted to obtain data on the boiler operation with this baffle arrangement.

The last of the constant-rating tests (Nos. 70 to 76) were made with the boiler baffled according to arrangement "C" shown in Fig. 4, during which Shipper "A" coal was burned.

Following the constant-rating tests, additional tests were conducted to determine the effect of blowing the flues at different intervals of time upon the temperature of the gases leaving the boiler. Tests Nos. 80 to 83 were conducted for this purpose, with intervals between blowing flues as follows:

Number of test	80	81	82	83
Interval between blowing flues, hours	4	12	24	8

During these tests the boiler rating was maintained at about 155 per cent.

The following nine days the boiler was banked during the night and over Sundays to determine the amount of coal required for banking. For the first five days a so-called "dead" bank was carried and during the last four days a floating bank. During the day period the boiler was operated at approximately 157 per cent of rating. A dead bank as used here is one in which the coal feed is entirely shut off and the fire is allowed to burn back as far as possible without permitting it to go out entirely. Small amounts of

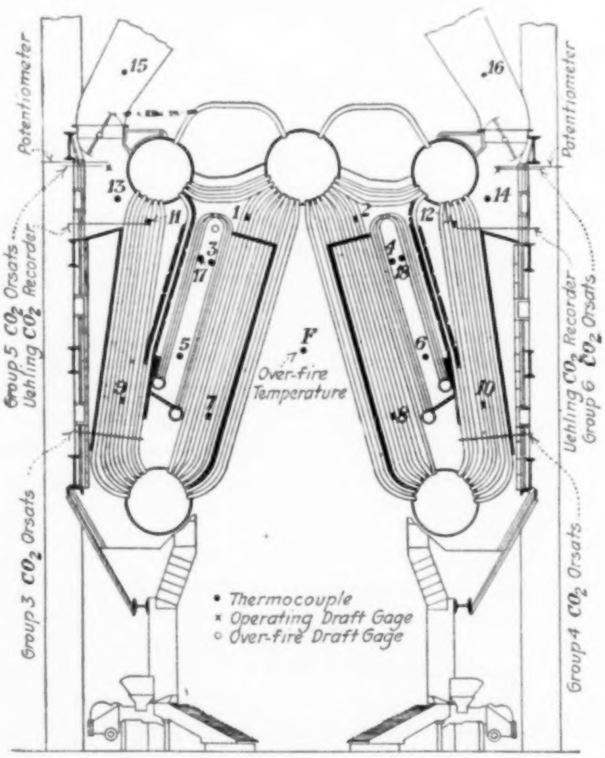

FIG. 3 "B" BAFFLE ARRANGEMENT

coal, just sufficient to keep the fire, are fed from time to time as required. During a dead bank a boiler will cease to steam, and the pressure will fall to atmospheric if the banking period is of sufficient duration. With a floating bank the coal feed is sufficient to keep the tuyeres well covered and to hold a fire which will maintain full pressure in the boiler. With a floating bank the boiler may even continue to steam at a very low rating throughout the banking period. Each banking test was divided up into overlapping periods with a different proportion between steaming and banking hours. The coal required for banking was computed by taking the difference between the coal actually used during a period and the quantity computed as being required to evaporate the water fed to the boiler during the same period. An average heating value of the coal used during each method of banking was taken as the standard, and all coal quantities were corrected to this standard heating value.

The last three tests conducted (Nos. 101–103) were strictly operating tests to determine the results of different methods of operating the boilers during the low-load period. Throughout these tests the steaming rate was varied according to the plant load, the boiler carrying its share of the total load during the day period. Test No. 101 was of 48 hr. duration with the boiler steaming at a low rate during the night. Test 102 was also of 48 hr. duration, but the boiler was subjected to a dead bank at night. Test 103

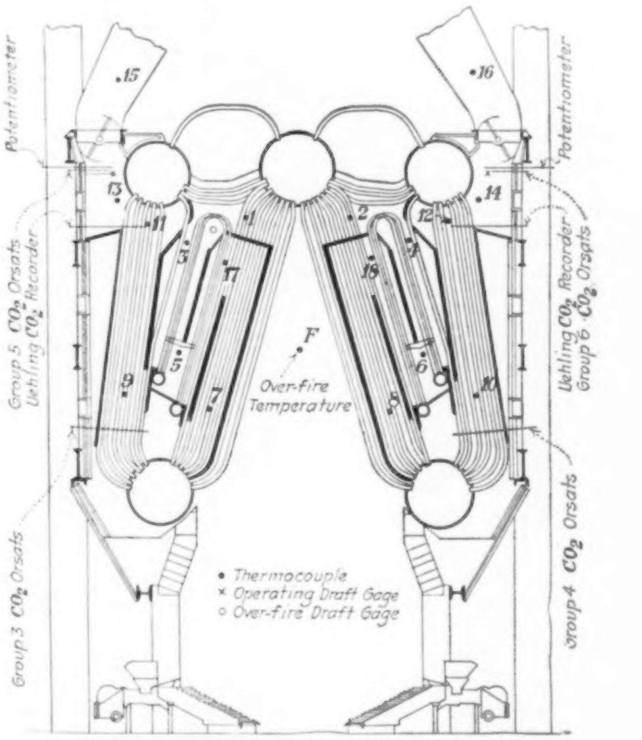

FIG. 4 "C" BAFFLE ARRANGEMENT

was of 25 hr. duration and the boiler was steamed at a rating of 90 per cent during the night.

Extended tables containing the data and results obtained over all these tests are on file at the Society's headquarters and may be consulted by any one interested in their contents.

DISCUSSION OF RESULTS

Baffle Arrangements. Figs. 5, 6, 7, 8 and 9 show the results of all the constant-rating tests in graphical form for the different baffle arrangements. Fig. 5 shows that before any changes had been made to the baffling the efficiency touched 79 per cent at 160 per cent rating. After the boiler was washed the efficiency curve was raised about 0.75 per cent, with a reduction in superheat. With the original baffling, Shipper "B" coal gave the highest efficiencies. These are shown in Fig. 6, in which are also plotted the points as reported by Dr. Jacobus in 1911 for the purpose of comparison. Fig. 8 shows the results obtained with the boiler baffled according to the "B" arrangement. These efficiencies were higher than with the original baffling, touching 83.5 per cent at 106.2 per cent rating. Due to the fact that the extension grates, which will be mentioned later, had been changed prior to this series of tests for others with larger openings, the combustible in the refuse was greater during the high-rating tests than with the original baffle. In order to correct for this loss, which is not chargeable to the baffle, a broken line has been drawn in to show what the efficiency would have been with an ashpit loss the same as during the first series of tests. With the "C" baffle arrangement the maximum efficiency reached was 82.4 per cent at 130 per cent rating. The results of this series of tests are shown in Fig. 9.

Each time the baffles were changed the row of tubes nearest the combustion chamber was partially cleaned by the workmen in making the changes, whereas the other tubes which were not touched

TABLE 4 PASS TEMPERATURES

Test No.	% Rating	Pass Temperatures. Deg. Fahr. Thermocouple Nos. 1&2	3&4	5&6	7&8	9&10	11&12	13&14	15&16	17&18	Temperature at damper, deg. fahr.	Over-fire temperature, deg. fahr.
2	116.0	1206	968	932	.....	581	547	497	....	....	547	1623
3	133.0	1274	1019	980	.....	628	576	513	....	....	587	1676
4	148.5	1320	1053	1002	.....	728	589	526	....	....	601	1708
5	163.7	1337	1071	1046	.....	671	605	547	....	....	623	1739
6	182.0	1398	1142	1109	.....	722	641	576	....	....	651	1756
7	199.0	1437	1190	1152	.....	760	666	597	....	....	685	1785
8A	215.0	1503	1238	1203	.....	819	705	630	....	....	719	1850
8B	210.0	1482	1222	1202	.....	830	710	621	....	....	710	1819
9	241.0	1588	1287	1257	.....	860	743	651	....	....	733	1899
10	268.0	1626	1335	1304	.....	914	782	651	....	....	782	2060
11B	79.0	799	721	730	.....	495	476	434	436	....	473	.....
12	102.8	901	773	791	.....	533	494	462	469	....	494	1260
13	53.2	685	655	664	.....	474	447	432	418	....	447	.....
14	126.2	1029	848	846	.....	566	509	495	486	....	504	1435
15	154.5	1149	917	928	.....	612	547	533	528	....	546	1574
16	180.0	1268	1041	1026	.....	680	602	591	575	....	607	1620
17	67.4	....	....	....	.....	.....	....	....	....	....	469	.....
18	216.7	1373	1102	1094	.....	722	638	627	608	....	645	1740
20	108.4	1024	838	852	.....	561	509	496	487	....	510	1383
21	153.3	1159	927	948	.....	623	562	549	543	....	572	1534
22	193.8	1299	1034	1046	.....	685	612	599	591	....	611	1652
23	224.9	1421	1146	1152	.....	773	685	681	657	....	690	1778
24	145.4	1216	989	968	.....	637	565	557	543	....	580	1540
30	151.4	1236	1001	977	.....	648	571	560	547	....	560	1596
31	115.0	1118	916	890	.....	578	521	507	496	....	530	.....
32	184.1	1284	1078	1055	.....	695	601	591	572	....	619	1771
33	216.5	1428	1137	1126	.....	754	647	637	616	....	655	1835
40	153.5	1190	964	972	.....	736	633	580	596	....	614	1612
41	199.0	1320	1056	1076	.....	827	711	659	670	....	691	1778
42	225.8	1421	1127	1154	.....	905	771	716	722	....	726	1835
43	108.0	1034	876	868	.....	686	590	537	555	....	566	.....
50	106.1	1077	890	888	.....	696	629	545	564	....	571	.....
51	137.0	1196	976	951	.....	738	631	575	587	....	604	1515
52	163.6	1296	1043	1029	.....	799	687	634	641	....	660	1647
53	194.3	1374	1118	1089	.....	846	721	669	671	....	682	1648
54	226.4	1427	1185	1173	.....	934	793	751	747	....	751	1698
60	196.4	1338	1053	1037	746	734	648	567	623	1157	601	1703
61	168.4	1299	1022	990	712	678	607	538	580	1114	558	1671
62	142.0	1272	1050	953	676	629	568	499	538	1080	526	1669
63	106.2	1159	920	844	600	551	504	443	479	978	466	1561
64	59.0	953	781	705	535	484	455	407	428	824	407	.....
65	148.5	1284	1015	962	691	635	567	503	542	1092	527	1733
66	212.5	1413	1118	1102	826	760	679	591	638	1227	620	1769
70	190.0	1339	1185	1012	680	620	663	524	571	677	547	.....
71	162.0	1282	1119	949	629	576	642	487	548	641	522	.....
72	134.0	1239	1086	914	607	557	627	475	528	634	499	.....
73	105.3	1111	966	821	543	516	519	423	468	588	424	.....
74	149.0	1293	1128	944	636	619	603	497	539	667	507	.....
75	183.2	1393	1256	1087	698	679	653	536	577	725	558	.....
76	208.5	1443	1298	1129	731	707	682	552	589	754	566	.....

TABLE 5 COMPUTED PERCENTAGE OF HEATING SURFACE PASSED BY GASES

Thermocouples	Percentage of heating surface passed over by flue gases: Original baffle	"A" baffle	"B" baffle	"C" baffle
Over-fire	0	0	0	0
Nos. 1 & 2	38.8	38.8	18.8	18.2
Nos. 3 & 4	50.6	50.6	28.2	23.4
Nos. 17 & 18	.....	.....	28.2	38.8
Nos. 5 & 6	58.5	58.5	41.2	31.8
Nos. 7 & 8	.....	.....	51.2	53.3
Nos. 9 & 10	74.6	74.6	71.2	76.6
Nos. 11 & 12	95.0	95.0	95.0	95.0
Nos. 13 & 14	100.0	100.0	100.0	100.0
Nos. 15 & 16	100.0	100.0	100.0	100.0

would retain their soot deposit. When comparing "B" and "C" with the original baffling this difference in condition of heating surface should be kept in mind. The "B" baffle shows a lower stack-gas temperature and higher superheat which at its best point gives an efficiency $2^1/_2$ per cent above the efficiency obtained with the original baffling; the best point, however, being

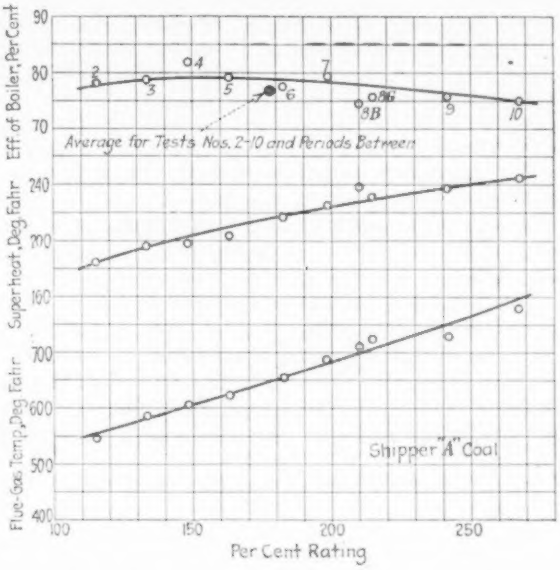

Fig. 5 Results Obtained with Original Baffle

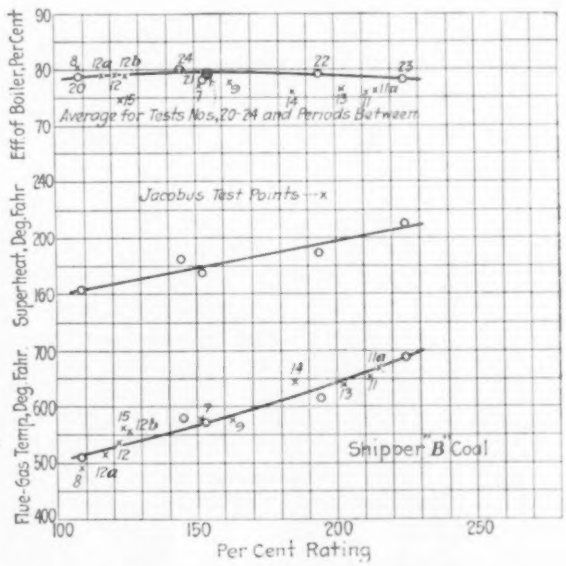

Fig. 6 Results Obtained with Original Baffle

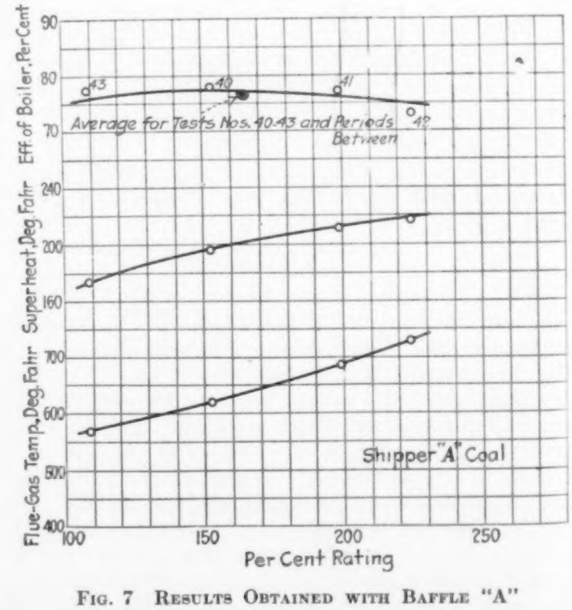

Fig. 7 Results Obtained with Baffle "A"

at a lower rating than before. Comparing the average efficiencies obtained during the entire series of tests on the original baffle before washing with the average obtained during the entire series of tests on the "B" baffle arrangement, we find that the original baffle gave 76.8 per cent at 178 per cent rating and the "B" baffle 79.1 per cent at 145 per cent rating. These results include all periods between the tests of the respective series, and one starting and burning-out period. With the original baffling after washing, the first five tests (Nos. 11–15) gave an average efficiency of 79.5 per cent at 99 per cent rating, and tests Nos. 16–18 gave 79.7 per cent at 122.8 per cent rating. From the results as shown in the heat balance (Table 6), it is apparent that these efficiencies are too high.

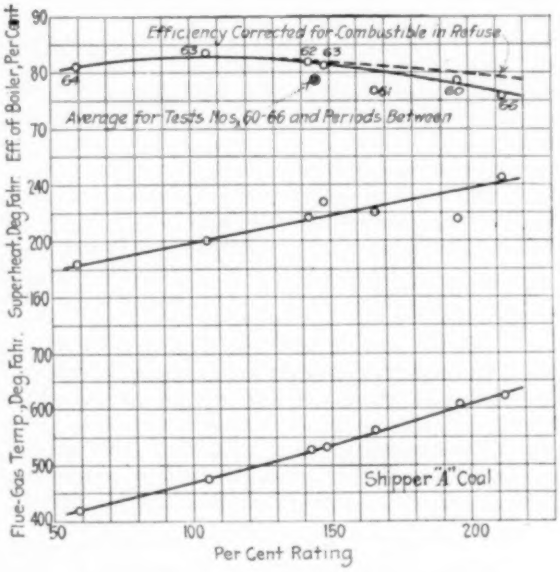

FIG. 8 RESULTS OBTAINED WITH BAFFLE "B"

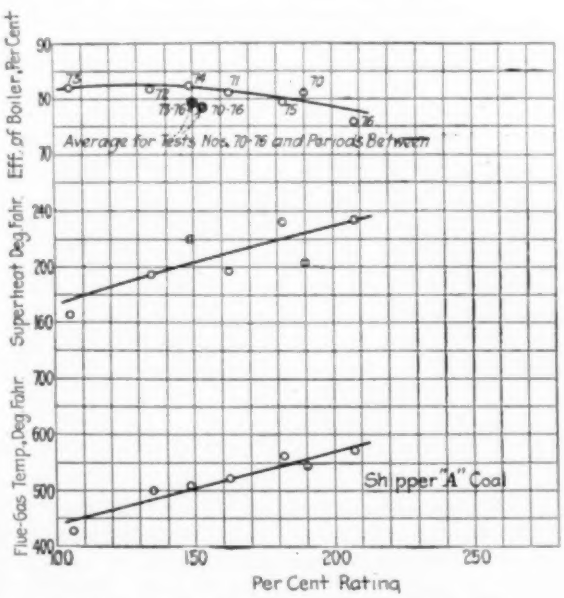

FIG. 9 RESULTS OBTAINED WITH BAFFLE "C"

A comparison between the average results obtained with the "B" and "C" arrangements shows the former to be 79.5 per cent at 145 per cent rating and the latter 79.8 per cent at 157 per cent rating. The gain, however, is not believed to be due entirely to the baffle arrangement, as a separation of the furnace, grate, and boiler losses show that for the "C" arrangement the unavoidable losses were 0.7 per cent lower than for the "B." Granting that a gain of 0.3 per cent in efficiency is accounted for by the "C" baffle arrangement, the fact that the "B" baffle gave a higher superheat makes it more desirable from the standpoint of overall plant economy, due to the effect of additional superheat on reducing the turbine water rate.

Extension Grates. During the tests, extension grates with different-sized openings were installed with the object of reducing the combustible in the refuse by furnishing more air over the grinders. Three different arrangements were made, including the standard grates which were in use at the beginning of the test. These original grates had a total area of openings of 11.76 sq. in. per set. At the completion of test No. 10 new grates having a total area of openings of 17.15 sq. in. were installed. Just before test No. 40 another change was made by increasing the air openings through the five top bars, leaving the two bottom bars as before. The total area of openings per set was then 25.40 sq. in. The damper control was also changed and improved to give closer regulation of the air to the extension grates. This last change did not give the expected results since the combustible in the refuse increased from 3 to 5 per cent over that obtained with the original grates. Although the ash content of the coal was about 1 per cent greater than during the first series of tests, it is not believed that this could account for the increase in combustible in the refuse, since the average rating carried with the original grates was considerably higher than after the second change. The effect of the second change in extension grates should be determined from tests Nos.

TABLE 6 HEAT BALANCE

Test No.	% Rating	Heat absorbed by boiler	Loss due to moisture in coal	Loss due to hydrogen	Heat Lost to Stack in: Theoretical dry gas	Excess dry air	Moisture in air	Total	Loss due to incomplete combustion	Loss due to combustible in refuse	Radiation and unaccounted for	B.t.u. in coal as fired
2	116.0	77.9	0.3	4.5	8.9	3.0	0.2	12.1	0.5	1.9	2.8	12690
3	133.0	78.3	0.4	4.8	9.5	3.7	0.1	13.3	0.6	1.9	0.7	12650
4	148.5	81.2	0.5	3.9	9.7	3.9	0.2	13.8	0.6	2.0	-2.0	12425
5	163.7	78.9	0.5	4.5	10.1	3.2	0.2	13.5	0.4	1.8	0.4	12750
6	182.0	77.3	5.6	4.3	10.9	3.4	0.1	14.4	0.4	3.0	-0.03	12550
7	199.0	79.8	0.6	4.5	11.7	2.7	0.1	14.5	0.7	2.3	-2.4	12277
8A	215.0	75.4	0.7	4.4	12.0	3.0	0.2	15.2	0.6	3.0	0.7	12432
8B	210.0	74.4	0.5	4.4	11.8	4.1	0.2	16.1	0.7	3.0	0.9	12595
9	241.0	75.4	0.7	4.4	12.1	2.6	0.2	14.9	0.5	1.9	2.2	12550
10	268.0	75.2	0.6	4.6	13.0	2.9	0.3	16.2	1.1	1.2	1.1	12540
11B	79.0	75.8	0.5	4.1	7.2	5.1	0.3	12.6	0.5	1.8	4.7	12780
12	102.8	78.1	0.6	4.3	7.1	5.0	0.2	12.2	0.5	3.1	1.1	12563
13	53.2	76.0	0.4	4.3	7.0	6.6	0.2	13.8	0.6	2.3	2.6	12860
14	126.2	83.1	0.6	4.0	8.2	2.1	0.1	10.4	0.4	1.8	-0.3	12580
15	154.5	80.3	0.4	4.2	8.9	2.6	0.2	11.6	0.4	3.8	-0.8	12677
16	180.0	80.5	0.4	4.0	9.8	3.1	0.2	13.1	0.2	2.6	-0.8	12425
17	67.4	79.5	0.5	3.9	7.2	5.0	...	12.2	0.5	2.1	1.3	12730
18	216.7	80.5	0.3	4.0	10.6	2.8	0.2	13.6	0.3	2.9	-1.6	12690
20	108.4	79.0	0.4	4.1	8.1	4.2	0.2	12.5	0.5	2.0	1.7	13100
21	153.3	78.3	0.4	3.6	9.1	4.0	0.1	13.2	0.4	1.4	2.7	13280
22	193.8	79.9	0.4	4.7	9.6	1.8	0.1	11.5	0.5	1.7	1.2	13220
23	224.9	78.1	0.3	4.3	11.2	1.9	0.2	13.3	0.6	1.5	1.8	13330
24	145.4	80.0	0.3	4.2	7.7	4.3	0.2	12.2	0.4	1.6	1.3	13540
30	151.4	78.8	0.4	4.0	9.1	2.9	0.2	12.2	0.4	3.5	0.7	12305
31	115.0	78.6	0.3	4.2	8.4	2.6	0.2	11.2	0.2	4.0	1.5	12283
32	184.1	75.6	0.4	4.1	9.8	2.4	0.3	12.5	0.3	2.6	4.5	12300
33	216.5	77.1	0.3	3.8	10.8	2.7	0.3	13.8	0.3	4.1	0.6	12390
40	153.5	77.9	0.5	4.3	10.2	3.9	0.2	14.3	0.3	3.3	-0.6	12240
41	199.0	76.7	0.5	4.5	11.5	3.7	0.3	15.5	0.2	3.1	-0.5	12580
42	225.8	72.9	0.4	3.9	12.5	3.4	0.3	16.2	0.4	3.6	2.6	12813
43	108.0	77.3	0.5	4.2	9.3	6.2	0.2	15.7	0.5	4.1	-2.3	12357
50	106.1	77.5	0.5	4.2	9.2	6.6	0.2	16.0	0.3	4.8	-3.3	11913
51	137.0	76.0	0.5	4.3	9.8	4.4	0.2	14.4	0.2	3.6	1.0	12072
52	163.6	75.0	0.4	3.7	10.9	4.3	0.3	15.5	0.2	4.6	0.6	12380
53	194.3	76.0	0.3	4.3	10.9	2.6	0.3	13.8	0.3	4.7	0.6	12530
54	226.4	70.9	0.4	4.1	12.4	2.5	0.4	15.3	0.5	7.3	1.5	12260
60	196.4	78.5	0.5	4.1	9.8	1.6	0.3	11.7	0.4	4.3	0.5	12200
61	168.4	77.0	0.4	4.1	8.8	1.7	0.4	10.9	0.4	3.1	4.1	12445
62	142.0	81.7	0.5	4.5	8.3	1.4	0.2	9.9	0.4	2.5	0.5	12240
63	106.2	83.5	0.5	3.9	7.0	1.7	0.2	8.9	0.4	2.7	0.1	12261
64	59.0	80.9	0.3	4.2	6.1	3.3	0.2	9.6	0.1	2.8	2.1	12549
65	148.5	80.8	0.4	4.7	8.0	1.1	0.3	9.4	0.4	3.8	0.5	12220
66	212.5	75.8	0.4	3.8	10.3	1.5	0.3	12.1	0.4	5.6	1.9	1229[illegible]
70	190.0	80.4	0.3	3.7	8.5	2.0	...	10.5	0.4	4.4	0.3	12730
71	162.0	81.3	0.4	3.6	7.8	2.2	0.4	10.4	0.4	3.3	0.6	12340
72	134.0	82.0	0.5	3.7	7.4	1.9	0.4	9.7	0.4	3.3	0.4	12149
23	105.3	82.2	0.3	3.6	6.3	1.8	0.2	8.3	0.3	2.6	2.7	12550
74	149.0	82.4	0.6	3.8	7.7	2.3	0.2	10.2	0.3	2.1	0.6	12118
75	183.2	79.8	0.6	3.7	8.8	2.2	0.2	11.2	0.3	2.7	1.7	12410
76	208.5	75.6	0.5	3.6	8.6	2.0	0.3	10.9	0.4	3.2	5.8	12650

60–67 and 70–76. Comparing the combustible for those tests with that obtained before and after the first change, it is seen that at low ratings the percentage after the second change was only very little greater than after the first one, although from 2 to 3 per cent greater than with the old type, and that the high averages are caused by greatly increased losses at higher ratings. That this increased loss due to combustible in refuse was due to the arrangement of air openings in the extension grates, is verified by the fact that at the completion of all tests the boiler was put back into regular plant operation, and the same difficulty with down blast through the grinders was experienced as during the test. Grates of the old type were then installed and additional observations were made at the same ratings as before, with the result that there was no down blast and the refuse contained about the same percentage of combustible as during tests Nos. 2–10.

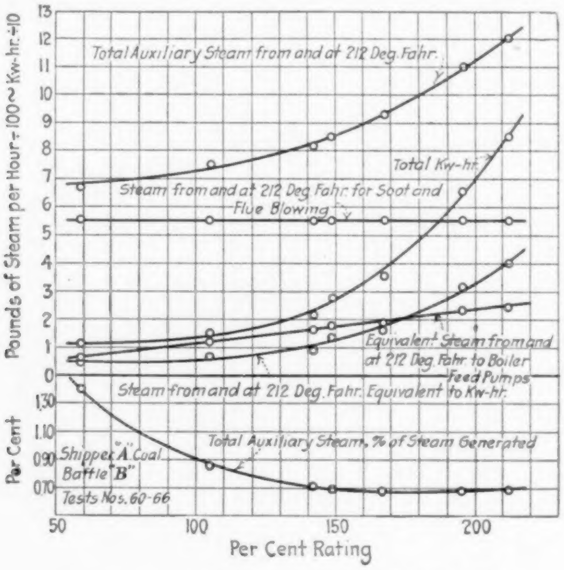

FIG. 10 AUXILIARY ENERGY REQUIRED PER HOUR

Air Supplied to Stoker. It will be seen from the results obtained from the Thomas air meter that this method of measuring the air supplied for combustion was not accurate, due to the leakage of air from the air chamber beneath the stoker. The results indicate that at high ratings the blower supplied over 25 per cent more air than was actually delivered through the stoker tuyeres. The Thomas air meter was checked against a 36-in. orifice with rounded entrance and was found to be an accurate means of measuring the quantities of air supplied by the forced-draft fan, but due to leakage from the air chamber the results could not be used for combustion computations.

Results Obtained with Different Coals. Data on the four different coals used in the tests are given in Table 2. Inasmuch as the different coals were not tested under identical conditions as regards boiler and stoker, the efficiencies obtained are not directly comparable. Except for Shipper "D" the percentage of CO_2 was about the same for the different coals, so the comparison may be made on the basis of the ashpit loss only.

Pass Temperatures. Figs. 1, 2, 3, and 4 show the points on a cross-sectional view of the boiler at which temperatures were taken, and Table 4 gives the temperatures at the different points. The readings of the thermocouples at symmetrical points in the two halves of the boiler have been averaged, and these averages are given in the table instead of the temperatures at each individual point. The over-fire temperature (point *F*) is the average of the two readings taken, one at the north and one at the south end of the combustion chamber. Points 15–16 are the average of the two readings 15 and 16, while every other point is an average of four; for instance, a point marked 3–4 is the average of thermocouples 3*S*, 3*C*, 4*N* and 4*C*. Observations obtained at point *F* are not correctly the temperature in the furnace due to the radiant heat given to the front rows of boiler tubes.

The heating surface as shown in Table 5 was computed on the basis of effective heating surface, assuming the superheater surface to have the same effectiveness in absorbing heat as the remainder of the boiler. Computations were made which showed the superheater absorbs about the same amount of heat per square foot as the average for the boiler.

Heat Losses. Table 6 gives the losses itemized in percentages of the total heat supplied in the coal. The loss due to combustible in refuse is based upon the percentage of combustible in the refuse and is computed by assuming that the refuse lost through the stack contains the same percentage of combustible as the refuse from the ashpit. Presumably the refuse to the stack contains more combustible than was shown by the analysis of the ashpit refuse, so the losses under this heading probably are slightly under the correct values.

In the radiation and unaccounted-for losses are included radiation from the boiler setting, loss due to sensible heat in refuse, loss due to unburned gases other than CO, and all errors involved in observation and analysis. Due to the fact that this item in most cases is small compared with results obtained in other tests, a few words of explanation are given to show that the radiation on this type of boiler is very low. Mr. H. Kreisinger[1] gives the radiation per square foot of exposed surface as 250 B.t.u. per hr. at 100 per cent rating and 350 B.t.u. per hr. at 200 per cent rating. The total exposed surface of this boiler, including steam drums, is 4294 sq. ft., or 1.81 sq. ft. per rated boiler hp., giving a radiation loss per hour per rated boiler hp. of 453 B.t.u. at 100 per cent rating and 634 B.t.u. at 200 per cent rating. The coal burned per rated boiler hp-hr. is practically a straight-line function between 50 per cent and 225 per cent rating, which gives 3.4 lb. per hr. at 100 per cent rating and 6.77 lb. per hr. at 200 per cent rating. This gives the radiation loss per pound of coal as 133 B.t.u. (1.06 per cent) at 100 per cent rating and 95 B.t.u. (0.76 per cent) at 200 per cent rating, assuming a coal of 12,500 B.t.u. per lb. as fired. An effort was made to check these values by computing the radiation losses on the bases of the exposed surfaces and certain temperatures, some of which were actually measured on a boiler of this type, and some assumed. Conservative values of heat-transmission coefficients were taken, with the result that the calculation gave the radiation per pound of coal as 75 B.t.u. (0.60 per cent) at 100 per cent rating and 40 B.t.u. (0.32 per cent) at 200 per cent rating. With the exception of a few tests which were of too short duration or were otherwise unsatisfactory, the observed radiation losses did not depart from the computed radiation by more than 1.5 per cent of the heating value of the coal.

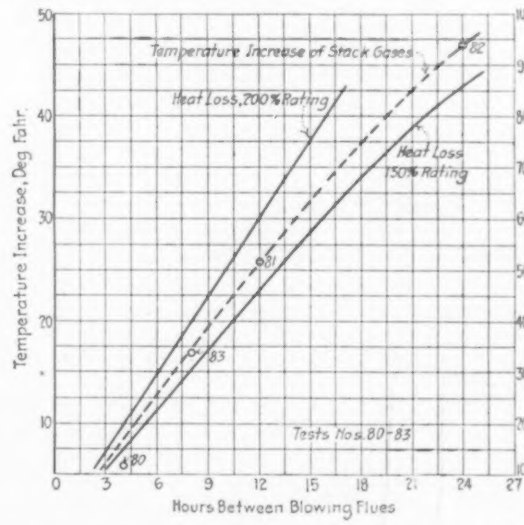

FIG. 11 EFFECT OF VARYING TIME INTERVAL BETWEEN BLOWING OF FLUES

ENERGY USED BY BOILER AUXILIARIES

The stokers, blowers, and grinders were driven by direct-current variable-speed motors, the electrical input to which was measured by watthour meters. This electrical energy was all generated

[1] Boiler Tests with Pulverized Illinois Coal, H. Kreisinger and J. Blizard, MECHANICAL ENGINEERING, May, 1921, p. 321.

on the auxiliary turbo-generators, the exhaust steam from which is all utilized for heating feedwater.

Fig. 10 gives for tests Nos. 60–66 the electrical energy required per hour for the blowers, stokers, and grinders, the steam equivalent to the electrical energy, and the total steam for all auxiliary uses expressed as equivalent steam from and at 212 deg. fahr.

Flue Blowing Banking—Variable-Rating Tests

Four tests (Nos. 80–83) were made to determine what effect varying the time interval between blowing flues would have on the temperature of flue gas leaving the boiler. In Fig. 11 the temperature increase has been plotted against the time interval between blowing. The B.t.u. loss per hour was computed from the mean temperature increase and is also shown in the same figure for ratings of 150 and 200 per cent.

The banking test included the period from August 13 to August 22. From August 13 to 18, the first period, dead banks were carried at night and over Sunday, and from the 18th to the 22d, the second period, floating banks were carried nights and Sunday. During the daytime the boiler was steamed at about 157 per cent rating. The results of these tests have been plotted in Fig. 12 and straight lines have been drawn through the points representing the two methods of banking. It seems probable that a straight line does not represent the true relation between the two variables, but the lack of sufficient data makes the determination of the exact relationship impossible.

These tests were conducted while the boiler was baffled according to arrangement "C." The two tests with low-rate steaming show practically the same decrease below the efficiency at constant rating (4 per cent and 3.8 per cent), whereas the test during which a dead bank was carried at night shows a decrease of 5.1 per cent.

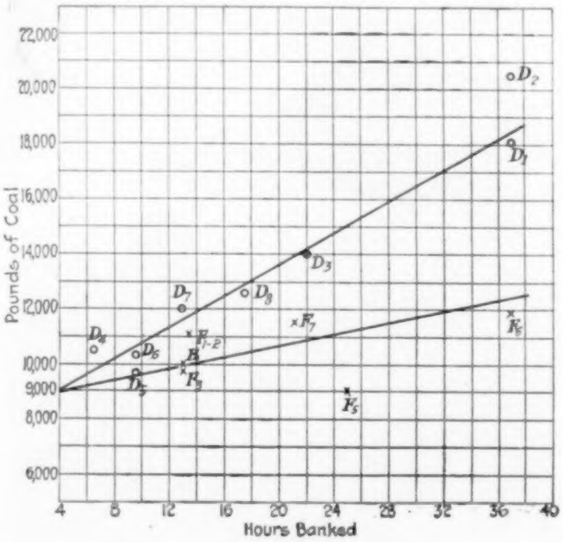

Fig. 12 Coal Required for Banking

When burning out the fires the coal was run entirely out of the spreaders and stoker hoppers, so that this amount of coal had to be added to or subtracted from the weighed coal over the starting or burning-out period. This loss and gain has been plotted against the per cent rating in Fig. 13. The ratings are those carried on the boiler at the end of the starting-up period and the beginning of the burning-out period.

Conclusions

Baffling Arrangements. The "A" baffing arrangement showed no improvement over the original arrangement except that the draft at the damper was reduced about 33 per cent.

With the "B" arrangement an average increase in superheat of over 20 deg. fahr. was obtained and the flue-gas temperature was reduced about 70 deg. fahr. as compared with the original baffling. The draft was also about 38 per cent less than with the original baffling. The results obtained indicated that there was very little difference between the "B" and "C" arrangements, and on account of the simplicity of the "B" arrangement and the fact that a slightly higher superheat was obtained, it was decided upon as the most practical arrangement to install in the present boilers.

Extension Grates. The changes made to the extension grates did not give the desired effect. After both the first and second changes the combustible present in the refuse was greater than with the old-type grates, and resulted from the trouble experienced with down blast which heated the grinders. It is believed that further

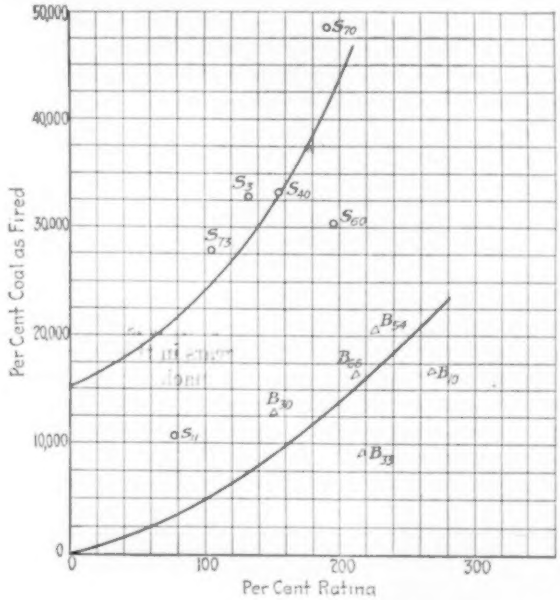

Fig. 13 Coal Lost or Gained in Starting Up and Burning Out Fires

study will develop a better arrangement of air openings, which will make possible a reduction in ashpit loss.

Air Supplied for Combustion. The method employed for measuring the air required for combustion was unsatisfactory, due to air leakage from the air chamber beneath the stoker, although the air passing through the meter was correctly indicated. This leakage amounted to as much as 25 per cent at high ratings.

Comparison of Coals. Shipper "B" coal gave only slightly better efficiency than Shipper "A" coal, while Shipper "C" coal was about 1 per cent and Shipper "D" coal 2.5 per cent lower than Shipper "A" coal. The results obtained, however, are not directly comparable due to the different arrangements of boiler baffling and conditions of the heating surface. A comparison on the basis of combustible lost in the refuse seems to be a better method. Expressed in percentage of dry coal the loss was:

Shipper	"B"	"A"	"C"	"D"
Per cent loss	1.60	2.25	3.68	4.25

Considerable difficulty was experienced with Shipper "D" coal due to the low fusion temperature of the ash, resulting in large clinkers, so that this coal was considered unsatisfactory. The other three burned satisfactorily, so that a consideration of cost f.o.b. plant, together with the relative value as fuel, determined the most economical coal. The results in this case were slightly in favor of Shipper "B."

Energy for Auxiliaries. The total energy consumed by the boiler auxiliaries averaged about 0.7 per cent between 170 per cent and 200 per cent rating, while at ratings near 50 per cent the energy consumed was 1.6 per cent. These figures are based upon the complete utilization of the exhaust steam in the feedwater heaters.

Flue Blowing. Taking into consideration the labor and maintenance costs directly influenced by the frequency of blowing flues together with the quantity of steam required per blow, an economic balance is obtained at 12.5 hr., assuming a constant rating of 200 per cent. Boilers banked at night should be blown only once a day. The foregoing is a literal interpretation of the test results which does not indicate exactly the proper procedure but serves more as a check on present practice.

Banking. Expressed in equation form, the coal required for the two methods of banking is:

Continued on page 44)

Testing Involute Spur Gears

By M. ESTABROOK,[1] NEW YORK, N. Y.

In this paper two new devices for testing spur gears are described: namely, the Saurer gear-testing machine, a Swiss development by means of which the accuracy of the tooth curves, spacing, and eccentricities can be determined with a high degree of precision; and the odontometer, an American instrument for quickly and accurately testing gears for tooth curves and spacing, and which can be used during the processes of manufacture, making it possible to locate troubles in the machines or tools.

IN MODERN machine construction it has been found advantageous to pay close attention to the inspection of component parts, as in this way much time can be saved in the final assembly. Gears, however, being more intricate than most parts, have not been inspected with as much precision as other machine components.

The most commonly used method of inspecting gears is that of rolling them on centers by hand. However, it is difficult to locate the exact trouble with a pair of faulty gears in this way.

The well-known type of gear-testing machine consisting of one fixed spindle and one adjustable spindle is usually employed for testing gears on centers. This indicator will show eccentricity, faulty spacing, or large teeth.

The gear-tooth vernier is commonly used to measure the thickness of gear teeth and accurate results can be obtained with it if the vernier is kept properly calibrated. The gear-tooth micrometer, however, consisting of a straight-sided rack tooth with micrometer adjustment for depth, is superior to the gear-tooth vernier in that the contact points are planes which wear relatively slowly, and it is easier to read than the vernier.

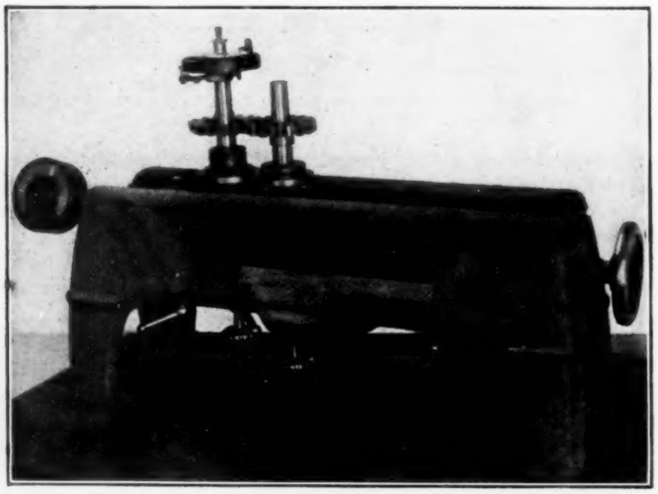

Fig. 1 The Saurer Gear-Testing Machine

An excellent method of testing large gears is to mount them on an arbor in a lathe and then arrange an indicator to bear against a plug inserted between the gear teeth.

The Kayle indicator is frequently used for testing tooth curves and consists of a straight edge arranged to roll on a disk the size of the base circle of the gear to be tested. A dial indicator shows any deviation from the true involute curve.

Projecting apparatus similar to that used for screw threads is sometimes used to examine gears, the tooth curves being compared with a correct profile.

Where large numbers of gears of a kind are to be tested, as in automobile manufacture, it is practical to devise special fixtures for testing the spacing and tooth curves of each gear. However, on account of the expense of making separate fixtures for each gear, this method is not used extensively.

The principal object of this paper, however, is to describe in detail two new devices for testing gears: the Saurer gear-testing machine, which was developed in Switzerland, and the odontometer, an instrument of American origin.

The Saurer Gear-Testing Machine

The Saurer gear-testing machine permits a more detailed study of a pair of gears than any of the devices commonly used, and with it the accuracy of the tooth curves, the spacing, and the eccentricity can be determined with a high degree of precision. The machine, shown in Figs. 1 and 2, consists of two spindles on which the gears are mounted. The spindles are also connected by two friction disks of which the diameters are the same as the pitch diameters of the gears to be tested. On one spindle there is a single sleeve which carries both the gear and its friction disk; on the other spindle there are two sleeves, one of which carries the second gear and the other the second friction disk.

When the first spindle is revolved its friction disk drives the other friction disk with a uniform velocity and its gear should drive the other gear with a uniform velocity if the gears have correct tooth curves and the spacing, etc., is accurate. In this case the two sleeves on the second spindle will revolve together. If there are inaccuracies in the gears, however, there will be a slight slippage between the sleeves. This slippage is magnified by a system of levers and a pen point traces the deviation. The magnification is about 100 to 1 for a 4-in. gear, or, expressed in another way, an angular variation of 1 min. is represented by $^1/_{16}$ in. on the chart. All of this error may be in one gear, or partly in one and partly in another. The chart shows errors in tooth curves, spacing, and eccentricity.

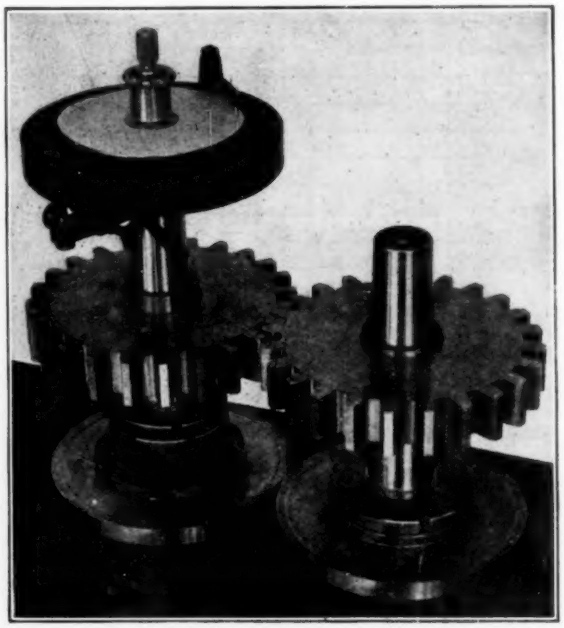

Fig. 2 Saurer Gear-Testing Machine, Showing Chart Being Traced

In any pair of gears there is almost always more than one kind of inaccuracy present, and, therefore, before proceeding to the examination of charts from the Saurer machine, it will be interesting to glance at Fig. 12, showing how the different kinds of errors are shown by the pen point on the chart.

A perfect gear gives a smooth circle or spiral. A spiral is produced when the friction disks are not of exactly the same diameters as the pitch diameters of the gears, but in many ways a spiral chart is preferable to a circular chart as it can be easily seen whether the

[1] Niles-Bement-Pond Co. Mem. Am.Soc.M.E.

Contributed by the Machine Shop Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

FIG. 3 CHART OF TWO 15-TOOTH MILLED GEARS SHOWING GOOD SPACING BUT FAULTY NORMAL PITCH AND TOOTH CURVES

(Gears 4 pitch, 14 1/2 deg. pressure angle; cut with form cutter marked "15-16 teeth.")

FIG. 6 CHART OF A 72-TOOTH MILLED GEAR RUNNING WITH A 24-TOOTH MILLED PINION, 4 PITCH. SHOWS GOOD SPACING BUT FAULTY TOOTH CURVES

FIG. 9 CHART OF A 72-TOOTH HOBBED GEAR RUNNING WITH A 24-TOOTH PINION

FIG. 4 CHART OF 16-TOOTH AND 31-TOOTH AUTOMOBILE GEARS, 6 PITCH, SHOWING POOR SPACING, POOR TOOTH CURVES, AND ECCENTRICITY

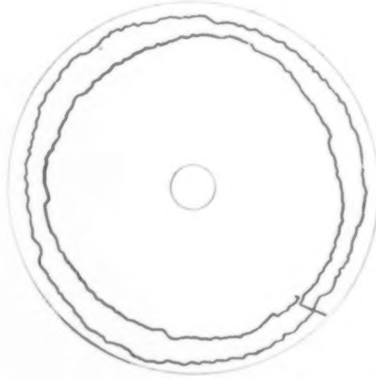

FIG. 7 CHART OF A 72-TOOTH MILLED GEAR RUNNING WITH A 24-TOOTH HOBBED PINION. SHOWS BETTER TOOTH CURVES THAN MILLED PINION, BUT POORER SPACING AND MORE ECCENTRICITY

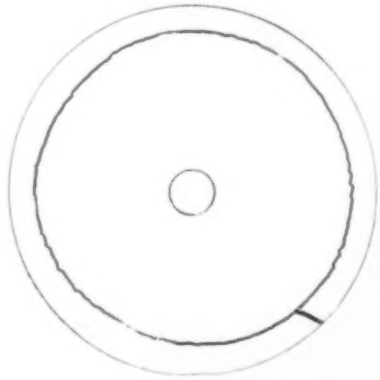

FIG. 10 CHART OF A 72-TOOTH MILLED GEAR RUNNING WITH A 24-TOOTH PINION, THE TEETH OF THE LATTER HAVING BEEN CORRECTED TO TRUE INVOLUTE FORM BY GRINDING

FIG. 5 SPIRAL CHART OF TWO 15-TOOTH GROUND GEARS. LARGE JUMP AT RIGHT CAUSED BY A HAIR INSERTED BETWEEN THE GEAR TEETH

FIG. 8 CHART OF A 72-TOOTH HOBBED GEAR RUNNING WITH A 24-TOOTH MILLED PINION. SHOWS FAULTY TOOTH CURVES AND ECCENTRICITY

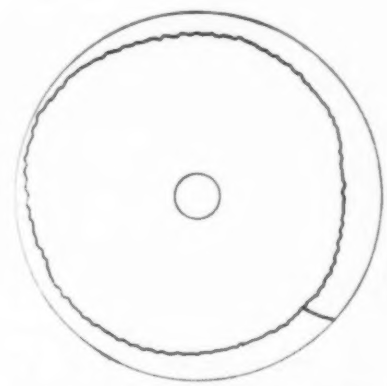

FIG. 11 CHART OF A 72-TOOTH HOBBED GEAR RUNNING WITH A 24-TOOTH PINION, THE TEETH OF THE LATTER HAVING BEEN CORRECTED TO TRUE INVOLUTE FORM BY GRINDING. CHART SHOWS SOME ECCENTRICITY

same errors are reproduced in successive revolutions of the gears. Spacing errors are shown by quick radial jumps in the curve. Incorrect normal pitch is shown by a gradual change and then a quick radial jump. Faulty tooth curves are shown by an irregular curve for each tooth in the gear. An eccentric gear makes an eccentric chart.

The chart of Fig. 3 was made by a typical pair of 15-tooth gears, cut with a rotary cutter marked 15–16 teeth. It shows that the tooth curves are not true involutes and that they do not drive with uniform velocities at all portions of the tooth profiles. This speeding up and slowing down of the driven gear during every tooth engagement causes noise at high speeds.

The chart of Fig. 4 was made by a pair of gears for a high-grade automobile. These were procured from a service station.

Fig. 5 shows a chart made by a pair of ground gears. It is a spiral and the same errors appear in the successive parts of the spiral; the large jump was caused by a hair inserted between the gear teeth.

The charts of Figs. 6 to 11, inclusive, were made by printing-press gears cut in different ways, and show how gear action can be studied by the use of the Saurer machine. In color printing it is important to avoid streaks or gear marks on the printed page, as when these occur the wear on the plates is excessive. For this reason presses for color work require especially accurate gears. The captions under the illustrations describe the charts in detail. The two circles in the charts of Figs. 6 to 9 are made by turning one gear 180 deg. around.

These charts are a great aid in studying the action of a pair of

gears and are of material assistance in running down gear troubles. It is interesting to note that in all cases where a milled pinion is used, the charts have the characteristic sawtooth form denoting departure from the true involute tooth form. This is not so noticeable with the milled gear as the gear-tooth outline, especially when the gear has a large number of teeth, is flatter and any modification from the true involute is less apparent. The pinion is the most critical part of a gear drive and it can be seen that when the pinions are correct the charts are almost perfect.

The Saurer gear-testing machine is also provided with a vernier for setting the spindles to correct center distances and with an indicator for rapidly testing gears for eccentricity and uniformity of

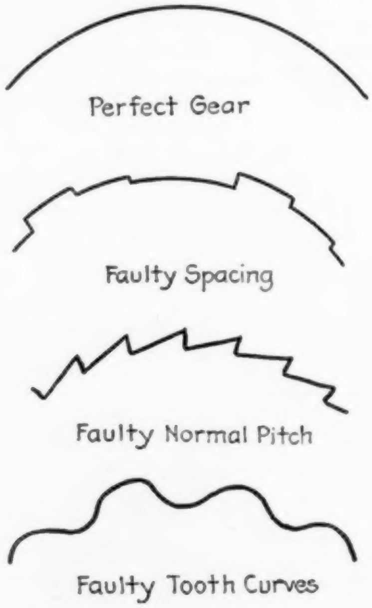

Fig. 12 Types of Charts Produced on Saurer Machine by Different Gear Inaccuracies

tooth thickness. One of the spindles is mounted on a slide that is held in position by a strong spring and is in contact with a dial indicator. When the gears are forced together this dial indicator should give a constant reading as the gears are revolved, if they are concentric.

The slide in contact with the indicator has ball bearings, making it sensitive to slight inaccuracies in the gears. It is comparatively easy to establish limits of eccentricity for any given gear when run with a master gear, and this application of the machine is useful in the commercial inspection of gears, as it is rapid, accurate, and sensitive.

The Odontometer

The odontometer was designed to meet the need for a quick, accurate gage to test gears for tooth curves and spacing. It is based on the principle that the involute curves of successive teeth are parallel—that is, the distance between the involutes measured on a normal is constant.

The instrument as shown in Fig. 13 consists of two rack teeth, one of which is fixed and the other is adjustable for different pitches. The adjustable tooth is mounted on flexible supports and is connected to a dial indicator. In use the instrument is allowed to roll in the gear to be tested. If the tooth curves are accurate involutes the needle of the dial indicator remains stationary while the two teeth of the instrument are in contact with the teeth of the gear; or, perhaps a better way of expressing it is to say that the needle pauses as the instrument is rolled in the gear. If the spacing is correct the needle pauses at the same point for each tooth. If there is no pause the tooth curves are not true involutes.

From Fig. 14 it will be seen that the odontometer does not test the whole tooth curve, but part of the dedendum of one tooth in relation to part of the addendum of the next. However, this is really the most important dimension because it is the overlap of the gears. That is, if this dimension is the same for all teeth, it means that when two teeth are driving each is taking its proportional part of the load.

To get good results from the odontometer the teeth of the gear should be smooth and should not be modified involutes. However, gears that are not true involutes can be tested for spacing errors with the odontometer.

The distance measured by the odontometer is the normal pitch, which is the same as the circular pitch on the base circle, and if the circular pitch on the pitch circle is desired, the distance measured should be divided by the cosine of the pressure angle.

In order that two gears may run together satisfactorily their normal pitches should be equal. In case there is any variation the normal pitch of the driver should never be less than the normal pitch of the driven gear.

One of the principal advantages of the odontometer is that it can be used during the process of manufacture and troubles located in the machines or tools. For instance, in grinding gears the odontometer can be used without removing the gear being tested from the machine or disturbing the setting. Further, it will measure gears designed to run at any pressure angle and can be quickly adjusted for different pitches. It can also be mounted on a stand

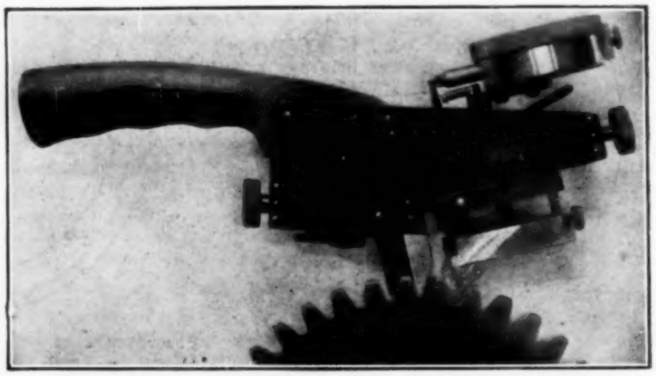

Fig. 13 Odontometer for Testing Gears of from 3 to 10 Diametral Pitch

(A smaller instrument is made for gears of 10 to 24 diametral pitch.)

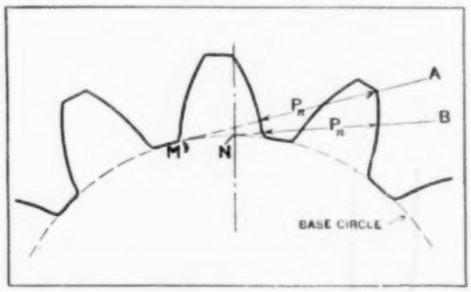

Fig. 14 Diagram Showing Part of Tooth Curve Measured by the Odontometer. Only the Part Between the Lines AM and BN is Measured

and used to measure the pinion-shaped cutters used in gear shapers.

In manufacturing, speed is of great importance and only those methods of testing gears should be selected that are relatively rapid. It should also be borne in mind that control of the equipment is fully as important as the inspection of the finished gears.

In the commercial production of precision-ground gears the Pratt and Whitney Company use the gear-tooth micrometer and the odontometer during the processes of grinding and subsequently test the finished gears by the hand-rolling or finger test and by the eccentricity test with dial indicator on the Saurer machine. The backlash and center distances are also checked on the Saurer machine and finally the gears are run under power for a noise test.

Nothing has been said regarding smoothness of tooth surface. This is an important point in the smooth running of gears, but as it is purely relative, definite limits cannot be fixed.

Attention should be called to the necessity of accurately mount-

(Continued on page 81)

Power Required for Cutting Metal

By FRED A. PARSONS,[1] MILWAUKEE, WIS.

This paper gives results of an investigation extending over a period of more than ten years, the purpose of which has been to determine the fundamental laws governing milling, turning, planing and drilling operations on the various metals and alloys used in machine construction. In addition to a very large number of tests made on milling machines constructed by the concern with which the author is connected, those reported by Frederick W. Taylor and Professors Bird and Fairfield in the Society's Transactions have been subjected to analysis, the following variables being studied:

1. *The efficiency of the machine*
2. *The rate of metal removal (cu. in. per min.)*
3. *The average thickness of chip before distortion*
4. *The front rake on the cutting blade*
5. *The material being cut*
6. *The spiral angle or shear on the cutting blade*
7. *The condition of the cutting tool, sharp or dull.*

The author's results are presented in the shape of formulas and tables by means of which the power required to machine metal in any given case may be calculated, and an example of their use is worked out in detail.

IN AN ARTICLE published in the technical press in 1920 were given the results of a preliminary study of a large number of milling tests run on Kempsmith milling machines. In the course of this study certain new laws were discovered, and a slide rule based upon them and constructed at that time gave very good results over the range of data then available. Later investigation over a wider range of tests showed, however, that further consideration was necessary, and it is the purpose here to give the results that have been obtained up to the present time.

The variables which may affect the relative power required at the drive pulley of a machine tool are, according to present data, limited to the following, there being no evidence that speed of cutting affects power economy to any marked degree:

a The efficiency of the machine
b The rate of metal removed (cu. in. per min.)
c The average thickness of chip before distortion (A.T.C.)
d The front rake on the cutting blade
e The material being cut
f The spiral angle or shear on the cutting blade (trifling)
g The condition of the cutting tool, sharp or dull.

It also seems likely that lubrication or flooding of the cutter may affect the power economy, but at present data on this point are not available.

In reality the seven variables mentioned above involve a variety of other factors, whose effect on the power required, however, is measured by their influence in fixing the value of the variables. These factors will be discussed in their proper place, as modifiers of the variables.

The data available were those of a very large number of tests made at the plant of the Kempsmith Manufacturing Company on various milling machines of their manufacture, and of other tests on power consumed, notably those of Taylor as given in his On the Art of Cutting Metals, and those of Professors Bird and Fairfield at the Worcester Polytechnic Institute (Trans. Am.Soc.M.E., vol. 26), these being chosen because the results were listed as "pressure on tool" or as "torque," from which the power to the tool itself could be computed and thus a distinction be made between the power required for cutting and that required for running the machine. The Kempsmith tests were mainly run under the following conditions:

a The machines were driven by a 25-hp. Crocker-Wheeler motor through a lineshaft having three roller bearings. This gave two belts and three roller bearings between the motor and the machine pulley

b The power input for each cut was measured by means of a voltmeter and ammeter connected through resistance across the line at the starting switch of the motor

c A reading was taken just before each test (1) of the motor, lineshaft, and machine pulley idle, and (2) of the same plus the machine with its speed and feed trains running but idle.

d The speed of the drive shaft of the machine was taken just before reading the instruments during the cut. This was done so that corrections could be made in the feed rate, from which the cubic inches of metal removed per minute was figured

e The readings for the power were taken after the cut was well under way, to make sure that the machine would really pull the cut. The No. 4 Maximiller originally incorporateda safety slip device in the feed train which caused considerable annoyance by reason of the fact that it worked too well, limiting the cut to the nominal rating of the machine, which was far under the actual limit of strength of the drive gearing or the capacity of the belt.

Some exceptions to the above conditions will be noted in their proper place.

Effect of Machine Efficiency

The efficiency of a machine is a variable quantity at different loadings. The power required to run the machine idle and the maximum efficiency of the mechanism at full load may be considered as determinants.

If a milling machine, for instance, is set up for a certain cut requiring, say, 1 hp. delivered to the pulley, and the width of the cut should then be increased fifteen times, the horsepower required at the drive pulley will not be increased in the same proportion. This is due to the increased efficiency of the machine at the new and larger load.

It was recognized that in order to arrive at consistent results the variations due to machine efficiency must be eliminated. Fig. 1 shows the efficiency at various loadings for two machines, one having 90 per cent maximum efficiency and the other 70 per cent. This chart was plotted as follows:

a The zero point in the efficiency curve was taken as 0.6 hp. from the average results of a number of tests of the power required to run the No. 4 Kempsmith Maximiller with all gearing running but idle

b The high points in the hp.-output lines were determined by a series of tests, which, while not very satisfactory, nevertheless showed that for a milling machine with anti-friction bearings a maximum efficiency of at least 90 per cent may be expected if the design is good, while for a machine having plain bearings throughout it may drop to as low as 70 per cent

c Taking these efficiencies as the extremes for milling machines of the two types gave the two lines for hp. output, and from the readings of these lines at intermediate points the values for plotting the efficiency curve were determined.

Referring to the first case mentioned, the 1 hp. delivered to the pulley would represent, according to Fig. 1, about $^1/_3$ hp. output from the machine, that is, to the cutter, on the 90 per cent machine. It is this value which must be increased fifteen times or to 5 hp. Again, reading from Fig. 1, this would require an input of 6 hp. or six instead of fifteen times the power for the first cut. The results on the 70 per cent machine would of course be somewhat different.

This all shows very conclusively that cutting tests must be corrected for horsepower and for machine efficiency before consistent results can be expected. The method used in doing this in these tests was to reduce all horsepower values to a value of "hp. delivered to the cutter" or tool hp. This can then be used to obtain a value of "cubic inches of metal removed per horsepower delivered to cutter," from which curves may be plotted for varying conditions.

[1] Chief Engineer, Kempsmith Milling Machine Co. Mem. Am.Soc.M.E.

Contributed by the Machine Shop Division and presented at the Annual Meeting New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

EFFECT OF RATE OF METAL REMOVAL

The horsepower varies directly as the cubic inches of metal removed per minute, but only if all the other factors remain constant. This would seem fairly obvious, but it has been very much obscured by the variations caused by other factors, especially the variation in machine efficiency at various loadings and the variation in proportionate chip pressure for different thicknesses of chip.

EFFECT OF VARYING THE AVERAGE THICKNESS OF CHIP (A.T.C.)

In the earlier investigation it was discovered that the power required for milling was closely related to the feed per tooth per revolution and to the depth of cut, the two items being considered separately. Later it was found that these items should be combined into an expression "Average Thickness of Chip" which influenced spiral and face mills alike (in fact, lathe tools, drills, etc. as well), gave uniform results over an extreme range of tests, and made proper allowance for the cutter diameter. Variations in the diameter of the cutter had been recognized during the first investigation as influencing the power required, but no definite law established which could be incorporated into the formulas.

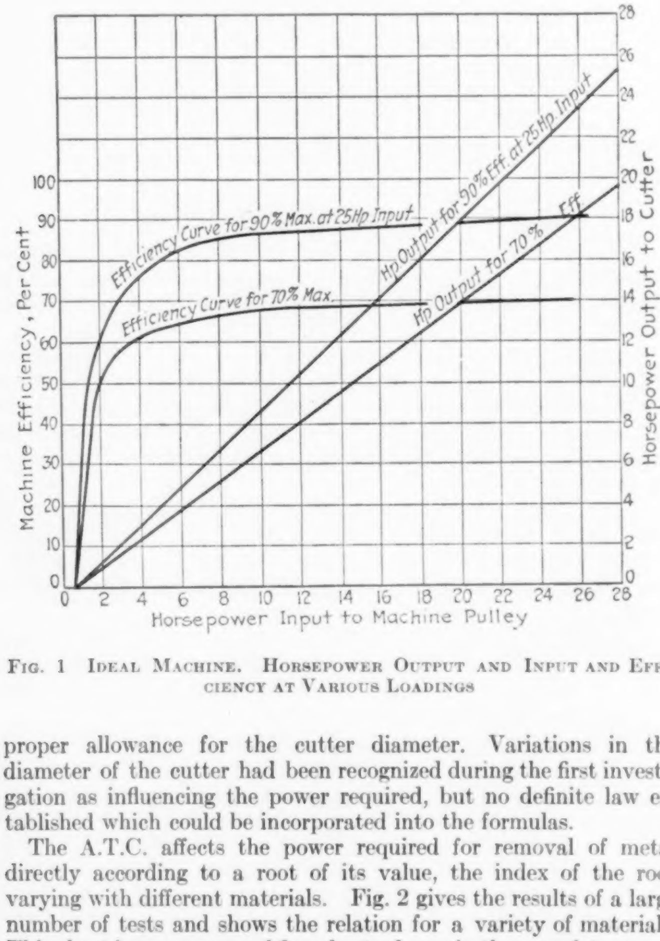

FIG. 1 IDEAL MACHINE. HORSEPOWER OUTPUT AND INPUT AND EFFICIENCY AT VARIOUS LOADINGS

The A.T.C. affects the power required for removal of metal directly according to a root of its value, the index of the root varying with different materials. Fig. 2 gives the results of a large number of tests and shows the relation for a variety of materials. This chart is a summary of five charts shown in the complete paper.

It will be noted that the tests charted include a considerable number for which the data were taken from the lathe tests run by Frederick W. Taylor and published by him in his book On the Art of Cutting Metals, as well as some drill tests run at the Worcester Polytechnic Institute. The fact that these tests fall into line with the milling-machine tests in such a completely satisfactory manner is considered as additional and very complete proof of the correctness of the general laws as formulated in Fig. 2. The logs of these tests are on file at the Society's headquarters and may be consulted by any one interested in their contents.

Several of the materials indicated in Fig. 2 have been tested for only a single point (see Table 1), and it is therefore not certain that the laws given for these should be considered as fully determined. From the fact that the lines for two materials, cast iron (machine castings) and soft steel, both come to a common point at about 0.0001 A.T.C., it is believed that this may safely be assumed for all other materials also. With this as a fixed point a single test is then sufficient to locate another, the two determining the direction of the line for the material tested, and thus determining the formula. The lines for aluminum and brass were thus determined. Those for steel and for machine cast iron were determined for nearly the full extent of the chart, and those for the other metals over a limited range only, but one sufficient to show that they apparently follow out the theory of a common origin for the lines of all materials.

TABLE 1 MILLING TESTS OF VARIOUS MATERIALS ON KEMPSMITH NO. 4 MAXIMILLER

Cutter: diam., $4\frac{1}{4}$ in.; no. of teeth, 14; deg. spiral, 25; deg. rake, 10; speed, 48 r.p.m. Cut: depth, 0.250 in.; width, $5\frac{3}{4}$ in.; feed per min., 6.27 in.; feed per rev., 0.13 in.; feed per tooth, 0.0093 in.; A.T.C., 0.0021 in.; cu. in. metal removed per min. 9.

Material	Test Sheet No.	Hp. to cutter	Cu. in. per hp. to cutter	Ratio of cu. in. per hp.
Cast iron (soft machine casting) through scale	4005–1	5.71	1.58	1.07
Do., no scale	4005–4	6.06	1.48	1.00
Cast iron (semi-steel 20%) through scale	4005–7	4.70	1.92	1.30
Do., no scale	4005–9	5.07	1.78	1.20
Steel casting, clean—no scale	4005–11	8.90	1.01	0.68
Steel bar (soft machine steel)	4005–12	10.30	0.88	0.60
Brass casting (yellow brass)	4005–14	4.00	2.26	1.53
Aluminum casting (commercial alloy)	4005–16	1.80	5.00	3.40

The A.T.C. for the various types of cutting tools must be determined in various ways according to the types, which, for this purpose at least, fall into five classes as follows:

a Spiral or slabbing mills
b Formed milling cutters, as gear cutters, etc.
c Face mills (1) with square corners on blades or (2) with corners rounded or chamfered
d Lathe and planer tools
e Drills, counterbores, etc.

For spiral or slabbing mills, and in general all milling cutters with the exception of formed cutters and face mills, it can be shown that the A.T.C. depends upon the feed per tooth per revolution, the cutter diameter, and the depth of cut, the relation being expressed with sufficient accuracy for all practical purposes by a formula derived as follows:

Let D = cutter diameter
R = cutter radius
d = depth of cut
f = feed per tooth per revolution of cutter
= feed per rev. ÷ number of teeth in cutter
A.T.C = average thickness of chip
t = maximum thickness of chip.

Then, referring to Fig. 3,

$$t = 2f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

whence—

$$\text{A.T.C.} = \frac{t}{2} = f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

The preceding formula is based on the following analysis: Referring to Fig. 3, in the triangle with the hypotenuse R the height is obviously $R - d$, and the base, from the law of squares, equals $\sqrt{2Rd - d^2}$. Since the triangle with hypotenuse f is similar to the triangle with hypotenuse R, their similar sides are proportional, or—

$$f : t = R : \sqrt{2Rd - d^2}$$

whence—

$$tR = f\sqrt{2Rd - d^2}$$

but—

$$R = \frac{D}{2}$$

$$\therefore t = \frac{2f}{D}\sqrt{Dd - d^2} = 2f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

Since the chip is a regular geometrical figure whose maximum height is t and whose ends are zero, its average height (average thickness of chip) is $\frac{1}{2}t$, or—

$$\text{A.T.C.} = f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)} \quad \ldots\ldots\ldots\ldots \text{[1]}$$

Formula [1] may be still further simplified by calculating and tabulating values of $\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$ for various values of the ratio $\frac{d}{D}$, as in Table 2, thus reducing to A.T.C. = $f \times$ constant. The

greatest value of the constant being 0.5 indicates that for slabbing mills the A.T.C. cannot be greater than half the feed per tooth per revolution, this maximum value being arrived at when the depth of the cut equals half the cutter diameter.

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Value of Ratio $\frac{d}{D}$	Equivalent Value of $\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$	Value of Ratio $\frac{d}{D}$	Equivalent Value of $\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$
0.001	0.0314	0.040	0.196
0.002	0.0445	0.050	0.218
0.003	0.0556	0.060	0.238
0.004	0.0630	0.070	0.256
0.005	0.0705	0.080	0.271
0.006	0.0770	0.090	0.286
0.007	0.0832	0.100	0.300
0.008	0.0890	0.200	0.400
0.009	0.0945	0.300	0.459
0.010	0.0995	0.400	0.490
0.020	0.140	0.500	0.500
0.030	0.170	....	....

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(Multiply A.T.C. obtained as for a spiral mill by the value corresponding to the ratio of d/W to obtain true A.T.C.)

Value of Ratio $\frac{d}{W}$ (See Fig. 4)	Value of W ÷ length of outline (approx.) (See Fig. 4)
0.5	0.67
1	0.45
2	0.24
3	0.16
4	0.12

against the edge of the circle generated by the revolving blades (see Fig. 5), it can be shown that the A.T.C. varies according to the ratio of the width of cut to the cutter diameter (W/D) and according to f, the feed per tooth per revolution. The A.T.C. for this type of mill is a definite ratio of W/D. (See Table 4.)

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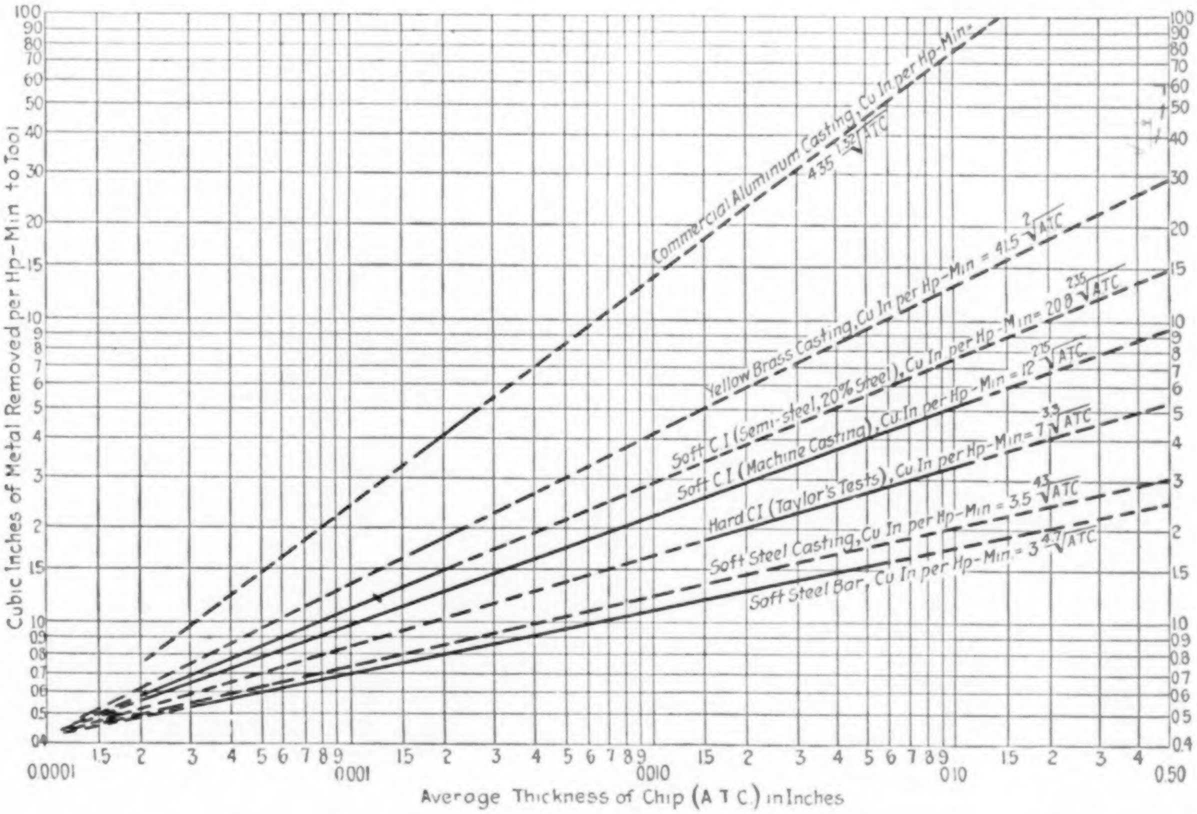

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For formed milling cutters the A.T.C. found by the above method must be reduced in proportion to the ratio of the width of the form divided by the length around the outline (see Fig. 4); or—A.T.C.

$$\text{for form cutters} = f\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)} \times \frac{\text{width of cut}}{\text{length around outline}}$$

This will be apparent if it is remembered that it is the *average* thickness of the chip which is required, and obviously if all the other factors remain the same an increase in the width of the chip as determined by the length of the outline will be accompanied by a corresponding decrease in the average thickness. This is explained more fully later in considering the effect of rounding on the corners of face mills.

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0.2	0.990f	0.7	0.853f
0.3	0.976f	0.8	0.800f
0.4	0.959f	0.9	0.716f
0.5	0.932f	1.0	0.500f

revolution; for if the chip *mop* is considered as a regular geometrical outline whose greatest thickness *op* is the feed per tooth per revolution (f), and which tapers regularly to zero at the ends, it will be seen that the average thickness of such a chip will be $\frac{f+0}{2} = \frac{f}{2}$. As the width of the cut becomes smaller in proportion to the diameter D (see width W, for instance), then the A.T.C. will approach the value of f, until for a zero width of cut the ends of the chip would have the same thickness as the center and the A.T.C. would be $\frac{f+f}{2} = f$.

To determine the exact A.T.C. for intermediate widths of cuts we may use the formula as determined for spiral mills and find the value of t (see Figs. 3 and 5). Since t for a face mill is the thickness

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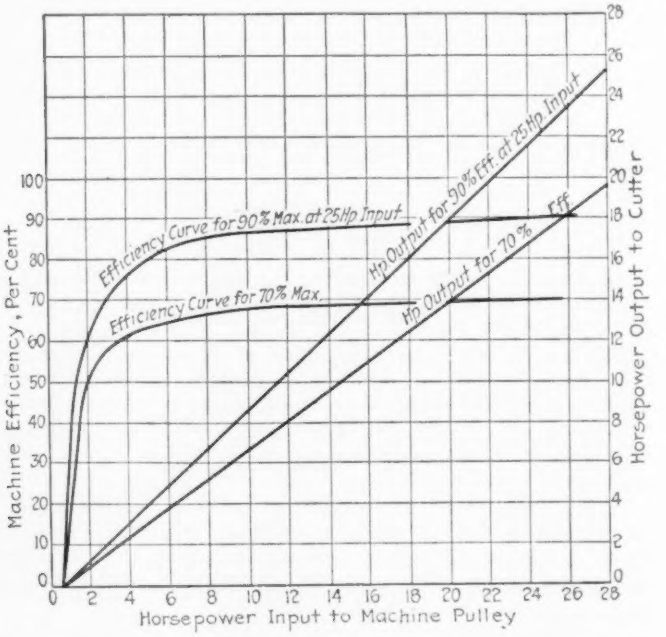

Fig. 1 Ideal Machine. Horsepower Output and Input and Efficiency at Various Loadings

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Then, referring to Fig. 3,

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whence—

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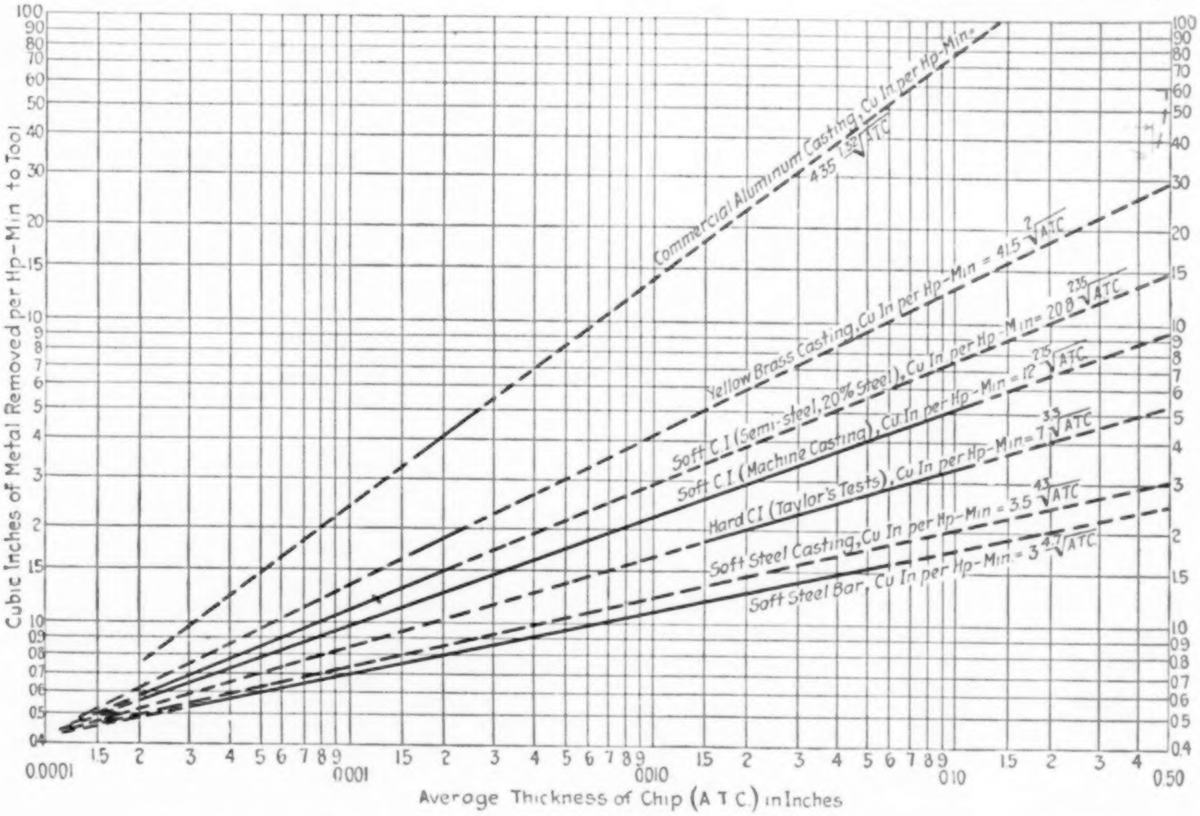

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A reasonable approximation may be had, however, if instead of employing the above method, which involves computing or measuring the outline, a constant be used representing the approximate value of W/(length of outline) for various values of d/W. Such constants are given in Table 3.

In practice the A.T.C. for form cutters should first be obtained as if for a spiral-mill cut, and then reduced as per the formula immediately preceding or by multiplying by the proper constant from Table 3.

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against the edge of the circle generated by the revolving blades (see Fig. 5), it can be shown that the A.T.C. varies according to the ratio of the width of cut to the cutter diameter (W/D) and according to f, the feed per tooth per revolution. The A.T.C. for this type of mill is a definite ratio of W/D. (See Table 4.)

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0.5	0.932f	1.0	0.500f

revolution; for if the chip *mop* is considered as a regular geometrical outline whose greatest thickness *op* is the feed per tooth per revolution (f), and which tapers regularly to zero at the ends, it will be seen that the average thickness of such a chip will be $\frac{f+0}{2} = \frac{f}{2}$. As the width of the cut becomes smaller in proportion to the diameter D (see width W, for instance), then the A.T.C. will approach the value of f, until for a zero width of cut the ends of the chip would have the same thickness as the center and the A.T.C. would be $\frac{f+f}{2} = f$.

To determine the exact A.T.C. for intermediate widths of cuts we may use the formula as determined for spiral mills and find the value of t (see Figs. 3 and 5). Since t for a face mill is the thickness

of the end of the chip, the A.T.C. for any value of W/D will be $\frac{f+t}{2}$.

The value of t as determined for spiral mills is found by the formula $t = 2f\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$, and the same formula holds for t in Fig. 5 if d be considered as the distance from the edge of the cutter circle to the work instead of being the depth of cut as for spiral mills.

For a face mill having any width of cut W, the value of d in the

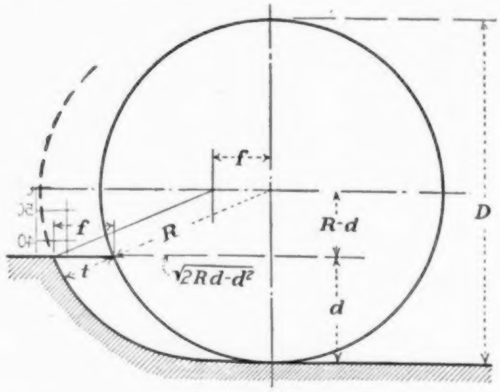


Fig. 3 Thickness of Chip for Spiral or Slabbing Tools

above formula may be expressed in terms of the diameter of cutter and width of cut as follows:

$$d = \frac{D}{2} - \frac{W}{2} = \frac{D-W}{2} = 0.5(D-W)$$

Then for face mills:

$$t = 2f\sqrt{\frac{0.5(D-W)}{D}\left(1-\frac{0.5(D-W)}{D}\right)}$$

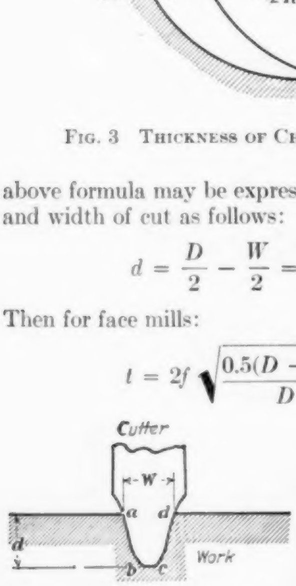


Fig. 4 Reduction in A.T.C. for Form Cutters

(W = width of form; d = depth of cut; $abcd$ = length of outline.)

It may be shown that the value of the term $0.5(D - W)$, and therefore the value of the preceding formula and also of the formula A.T.C. = $(f + t)/2$, will be constant for any given ratio of W/D if expressed in terms of f. (See list of such values in Table 4, which are much easier to use in computing A.T.C. than the formula.) The simplified formula for obtaining A.T.C. for face mills having square corners is therefore as follows, the constant being obtained from Table 4: A.T.C. = constant $\times f$.

For face mills having a corner radius on the blades, it can be shown that the A.T.C. as determined above for square-cornered mills must be decreased according to constants depending upon the ratio of the depth of cut d to the corner radius on blades r. (See list of these constants in Table 5.)

The method of arriving at these constants is as follows: If the corners of the blades are perfectly square (Fig. 6), then the width of the chip ($= ek$) is equal to the depth of the cut d, and the A.T.C. at all cross-sections of the cut will be the same.

If the corners are rounded (see Fig. 7), as is almost invariably the case in practice, the A.T.C. will vary at different sections of the cut, being a maximum only for sections of cut not coming on the radius of the cutter blade, as at A, and running down to zero at B. The real A.T.C. or average value of A.T.C. for all the sections would therefore depend upon the ratio of the depth of cut d to the corner radius r, or d/r. This real A.T.C. may for the moment be called A.T.C.^{R}, to distinguish from what may be called A.T.C.^{S} for a cutter with sharp corners.

Now if the average area of chip is computed by multiplying the average thickness (A.T.C.^{S}) as obtained for face mills with square blade corners by the depth of cut d, this value will not be changed by the addition of the corner radius since it is obvious that if a certain area of work is removed by taking a definite number of chips, determined by speed, feed, number of teeth in cutter, etc., each chip will have a definite area regardless of its form. This can be stated thus:

$$\text{Average area} = \text{A.T.C.}^S/d$$

The addition of a corner radius, however, will change the length from gh in Fig. 5 to AB in Fig. 7, and the real average thickness or A.T.C.^{R} will therefore change accordingly, or:

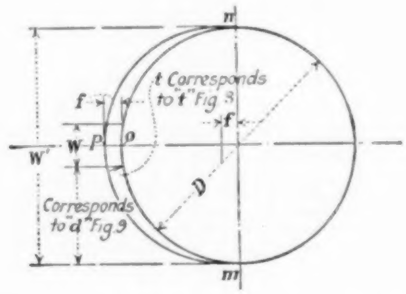


Fig. 5 Diagram Representing a Face-Mill Cut

(f = feed per tooth per rev; D = diam. of face mill; W, W' = various widths of cut; t = approx. end thickness of chip for cut of width W.)

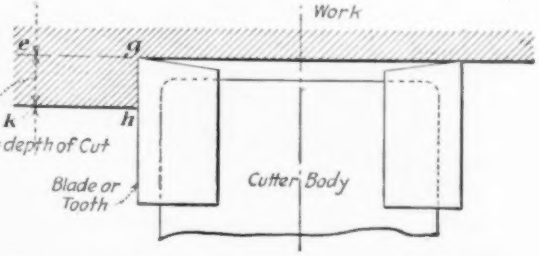


Fig. 6 Face Mill with Square Corners on Blades

$$\text{A.T.C.}^R = \frac{\text{average area}}{\text{length of chip}} = \frac{\text{A.T.C.}^S \times d}{\text{length}}$$

The length $A'B$ in Fig. 7 may be found by the formula—

$$\text{Length } A'B = 2\pi r \times \frac{\text{angle } S}{360°}$$

For any given value of d/r it can be shown that the length as expressed in terms of r will be constant and upon this basis it can also be shown that for any given value of d/r the value of A.T.C.^{R} will also be constant as expressed in terms of A.T.C.^{S}.

If these ratios are evaluated they result in the constants given in Table 5, by which the A.T.C. as determined for a given cut with a face mill having square corners must be multiplied to get the true A.T.C. for an equivalent cut with rounded or beveled corners.

TABLE 5 CONSTANTS FOR USE IN DETERMINING A.T.C. FOR FACE MILLS WITH ROUNDED CORNERS

(Multiply A.T.C. for equivalent cut with face mill having square corners by constant corresponding to value of depth of cut divided by corner radius on blades.)

Ratio $\frac{d}{R}$ (See Fig. 7)	Length of Chip $= A'B$ (See Fig. 7)	Average Area of Chip = A.T.C.$^S \times d$	Constant $= \frac{\text{area}}{\text{length}} = \frac{\text{A.T.C.}^S \times d}{A'B}$
0.1	0.445r	A.T.C.$^S \times 0.1r$	0.225
0.2	0.645r	A.T.C.$^S \times 0.2r$	0.31
0.4	0.925r	A.T.C.$^S \times 0.4r$	0.43
0.6	1.16r	etc.	0.52
0.8	1.37r		0.58
1.0	1.57r		0.64
2	2.57r		0.78
3	3.57r		0.84
4	4.57r		0.87
5	5.57r		0.90

A.T.C. for Lathe and Planer Tools

After having followed through the above it will be apparent that for lathe and planer tools the A.T.C. will also be dependent upon the form of the tool—

a If the tool has a sharp corner and acts square with the direction of feed, then the A.T.C. = feed per revolution or per stroke

b If the tool is rounded, or stands at an angle, the A.T.C. as determined above for the square-cornered tool must be

reduced to its true value by multiplying by the depth of cut and dividing by length of the chip, on the same principle as used in determining the true A.T.C. for face mills having rounded corners.

There are no accepted standards for tool forms in general use and therefore no table of constants can be given here, though these could easily be worked out for any standardized set of forms. For the lathe tests of Frederick W. Taylor which are incorporated in Fig. 2, the A.T.C. was modified as above according to the outlines of his standard tools as given in On the Art of Cutting Metals.

A.T.C. for Drills, Counterbores, Etc.

For counterbores, where the cutting edge is square with the feed, the A.T.C. = feed per revolution ÷ number of teeth in tool.

For drills the angle of the cutting edge must be considered. The A.T.C. as determined above should be multiplied by the cosine of the angle the cutting edge makes with the direction of the feed, which in the case of a drill ground to the standard angle of 59 deg. would be the cosine of 31 deg. or 0.857.

For the drilling tests the A.T.C. was determined as above, the cubic inches per horsepower-minute being reduced 20 per cent for the purpose of comparison with the standard line, as the line represents a tool half dulled.

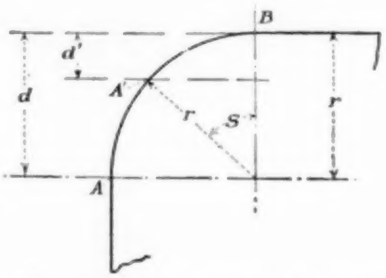


Fig. 7 Diagram of Rounded Corner of Face-Mill Blade or Tooth

(d, d' = various depths of cut; r = corner radius or equivalent bevel; A B, A' B = length of chip.)

Effect of the Front Rake of Cutting Blade on Power Consumed

Tests are available only for milling cutters, and only up to 12 deg. of rake (see Table 6). The results of such tests as are available seem to show that for milling cutters the power required varies directly as the ratio of the covered sine of the rake angle, or the cubic inches of metal removed per tool hp. varies inversely in the same way.

For milling cutters and lathe tools the front rake may vary considerably, and allowance according to the above should be made when computing metal removed or hp. required from the chart of Fig. 2, which is based upon milling cutters of about 10 deg. front rake and lathe tools of about 15 deg. front rake.

For drills the rake as determined by the helix angle is not subject to much variation in practice. Fig. 2 being based on drills having the rake angle of the standard twist drill (which is about equivalent to a 15-deg. average cutting rake), no allowance need be made when employing it unless the drill to be used is something other than a standard.

There is a possibility that front rake has different effects according to the material tooled, but this is not indicated to any marked extent in tests thus far available.

Power Required for Various Materials

Each material requires a different formula for determining the metal removed per hp-min. or the hp. required for any given cut—see Fig. 2.

It is apparently not possible to give any fixed ratio for the power required for different materials as this varies according to the A.T.C., the differences due to varying materials becoming small and negligible when the A.T.C. is reduced to a value of about 0.0001, as has been previously explained. The tests in Table 1 show the ratios of metal removed when the value of A.T.C. = 0.0021; ratios for other values of A.T.C. can be determined from Fig. 2.

Since allowance for various materials has already been made by the use of different lines on the chart, it is not necessary to consider this item when computing the hp. required or metal removed per hp. for any given cut, beyond choosing the proper formula or reading from the proper line.

Effect of Spiral or Helix Angle (Shear) on the Cutting Blade

It is important to distinguish between the action of a spiral angle or shear, as on a spiral milling cutter (which does not make the chip thinner), and the effect of setting a lathe tool on an angle, which thins down the chip by increasing its length while its area remains constant according to the feed in use in the same way that the chip thickness is decreased for a form cutter and for a face mill with round blade corners, as previously discussed, or by the angle on the point of a twist drill, which also thins down the chip. The effect of adding a spiral angle to a milling cutter, as far as power efficiency is concerned, seems to be largely confined to reducing the bumping action of the cut and thereby somewhat reducing the maximum power required. From the standpoint of power required this effect is not important.

A test run first with several narrow cutters set up with all the teeth on a line, and again run with the teeth staggered (to give the effect of a spiral cut), showed the power reduced in the ratio of 1.42 to 1.27 (Test sheet No. 4 Maxi. 4004-17-19).

The spiral angle is of considerable importance, however, from the fact that a large spiral angle will enable fewer teeth to be used in the spiral or slabbing cutter. The only reason for using many cutting teeth in such a cutter is in most cases to reduce the bumping action to a point where the work, jigs, and machine will stand it, and this can be done effectively with fewer cutting teeth if the spiral angle is large.

For the same reason a cutter with considerable spiral angle may take a heavier feed than one with small or no angle, though this is

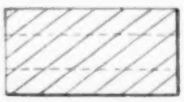



TABLE 6 EFFECT OF FRONT RAKE OF BLADES ON POWER REQUIRED FOR CUTTING METAL

Material cut, semi-steel; depth of cut, ¼ in.; width of cut, 5¾ in.; machine used, No. 4 Maximiller

Front rake B, deg.	Test Sheet No.	Cutter			Speed, r.p.m	Cut			Cu. in. metal removed per min.	Net hp. to cutter	Cu. in. per hp-min.	A.T.C. (Average thickness of chip) in.	Cu. in. per hp-min. revised for A.T.C. = 0.002 in.	Ratio of cu. in. per hp-min.	Ratio 1 / covers B
		Type and diam., in.	No. of teeth	Spiral, deg.		Feed per min., in.	Feed per rev., in.	Feed per tooth, in.							
0	4004-11	Sp., 3½	6	26	78	4.35	0.056	0.0094	6.25	4.50	1.39	0.0025	130 } 1.35	1.00	1.00
0	4004-19	Sp., 6	10	25	35	3.55	0.103	0.0103	5.1	3.60	1.42	0.0021	140 }		
5	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.10
7½	4004-15	Sp., 4¾	11	26	48	6.20	0.131	0.0119	8.9	5.40	1.65	0.0028	1.48	1.10	1.15
10	4004-9	Sp., 4½	14	25	63	8.65	0.137	0.0098	12.4	7.60	1.64	0.0022	1.60	1.19	1.21
12	4004-13	Sp., 4½	11	26	63	7.35	0.117	0.0106	10.4	6.30	1.65	0.0026	1.59	1.19	1.25
15	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.35
20	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.52
25	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.73
30	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	2.00

often prevented by interference of chips. The increase in the feed rate is, of course, equally as effective as a decrease in the number of teeth in increasing the cutting efficiency.

No tests are available for extreme spiral angles such as those of the helical mills sometimes used, but it is believed that the greater efficiency of these mills is almost entirely due to the decreased number of teeth and consequent increase in A.T.C., which would fully account for a greatly increased efficiency.

EFFECT OF SHARP AND DULL CUTTERS

The condition of the cutter has a very pronounced effect on the amount of power required for removing metal. It is believed that a good part of the variations above and below the line on the various charts are due to differences in the degree of cutter sharpness.

Tests showing the variations for sharp and dull milling cutters cannot be expected to show uniform results as there is no standard for dullness. However, a number of tests (see Table 7) show that the power may be expected to increase as much as 40 per cent or more before the appearance of the cut warns the operator that it is time to resharpen in the case of milling cutters.

As the economical time between grinds varies with different jobs, being sometimes one or more days and sometimes the period required to finish a given lot of pieces, according to various considerations, it seems best to consider the entire interval from sharp to dull as ten equal units, irrespective of the time involved. The tests—1217-7, etc., Table 7—show that the cutter dulls in a fairly regular manner, and on this basis the power required could be considered as increasing regularly to a maximum of about 40 per cent above that required with a newly sharpened cutter, at which point the operator would notice that it needed resharpening from the fact that it was no longer cutting properly.

In computing power required or metal removed per tool hp. from the chart of Fig. 2, we would, according to the above method, take the results from the chart as being for a cutter which had been used for five of the allotted ten units mentioned: in other words, a cutter which was just half dulled. The computed power required for any given conditions would then be increased if the cutter had been run *more*, or decreased if the cutter had run *less*, than the time or distance required to half dull it; while if computing metal removed per tool hp. this procedure would of course be reversed, the amount of increase or decrease naturally depending upon the number of units less or more than half dulled up to approximately 20 per cent over and under for the maximum of 5 units.

The preceding paragraph refers only to milling cutters. For drills no data are available, but when allowance is made as above, they fall almost exactly on the line corresponding to the half-dulled cutter. Lathe tools, to be run economically, as shown by Taylor in his On the Art of Cutting Metals, should be run at speeds which dull them very rapidly as compared with the economical speeds for milling cutters. It is therefore probably safest to consider all lathe tools as *dull* tools, because the time interval between a sharp and a dull tool is, or should be, comparatively very short. Exceptions to this are formed tools and other tools in automatic machinery, etc., where the cost of resetting makes it necessary, as for a milling cutter, to increase greatly the time interval.

This completes the consideration of the variables mentioned at the beginning of the paper as affecting the power required for cutting metal, and from what has been set forth may be figured the power required by the cutter for almost any combination of tool and cut. Belt hp. can only be computed if the idle hp. and efficiency under some known load are known, though it can be approximated if the last item only is known, especially if the cut represents a fairly large percentage of the machine's capacity.

EXAMPLE. To find the power required for a gang of 5 gear cutters of 6 pitch, No. 4, 3 7/16 diam., 13 teeth, when cutting in cast iron (semi-steel, 20 per cent steel) with a feed of 7 1/4 in. per min. and at a speed of 56.5 ft. = 63 r.p.m.

TABLE 7 POWER REQUIRED FOR DULL AND SHARP MILLING CUTTERS

Condition of Cutter	Machine	Test sheet No.	Material	Cutter: Type and diam., in.	Cutter: No. of teeth	Cutter: Spiral, deg.	Cutter: Rake, deg.	Speed, r.p.m.	Cut: Depth, in.	Cut: Width, in.	Cut: Feed per min., in.	Cut: Feed per rev., in.	Cut: Feed per tooth, in.	Cu. in. metal removed per min.	Hp to cutter	Cu. in. per hp-min. to cutter	A.T.C.	Corrected for	Cu. in. per hp-min. corrected	Ratio sharp to dull
Sharp	4P. Maxi.	2305–10	C.I.	Face mill	14	10	10	39.5	0.375	6	10.45	0.260	0.019	22.70	7.65	2.96	0.0062	none	2.96	1.45
Dull	"	2305–11	"	8½ in.	"	"	"	41.5	0.350	5	11.00	0.265	"	22.15	10.90	2.04	0.0059	"	2.04	
Sharp	"	2323–17	C.I.	Face mill	14	10	10	25.0	0.450	6	7.35	0.294	0.021	19.85	7.25	2.74	0.0069	none	2.74	1.29
Dull	"	2323–10	"		"	"	"	24.5	0.400	6	7.17	"	"	17.20	8.10	2.12	0.0066	"	2.12.	
Sharp	2P. Maxi.	1217–7	Steel casts	Sp. 3¾ in.	10	25	7	88	0.187	6	4.35	0.050	0.005	4.87	5.80	0.840	0.0012	none	0.840	1.29
Has run —																				
76 in. = 17 min.	"	1217–11	"	"	"	"	"	"	"	"	"	"	"	"	5.95	0.820	"	"	0.820	
132 in. = 30 min.	"	1217–14	"	"	"	"	"	"	"	"	"	"	"	"	6.30	0.775	"	"	0.775	
152 in. = 34 min.	"	1217–15	"	"	"	"	"	"	"	"	"	"	"	"	6.45	0.755	"	"	0.755	
190 in. = 43 min.	"	1217–17	"	"	"	"	"	"	"	"	"	"	"	"	6.75	0.720	"	"	0.720	
228 in. = 52 min.	"	1217–19	"	"	"	"	"	"	"	"	"	"	"	"	6.81	0.713	"	"	0.713	
256 in. = 60 min.	"	1217–21	"	"	"	"	"	"	"	"	"	"	"	"	7.03	0.692	"	"	0.692	
400 in. = 90 min.	"	1218–5	"	"	"	"	"	"	"	"	4.28	"	"	4.77	7.02	0.680	"	"	0.680	
475 in. = 108 min.	"	1218–9	"	"	"	"	"	"	"	"	"	"	"	"	7.10	0.670	"	"	0.670	
650 in. = 147 min.	"	1218–18	"	"	"	"	"	"	"	"	"	"	"	"	7.25	0.660	"	"	0.660	
720 in. = 164 min.	"	1218–21	"	"	"	"	"	"	"	"	"	"	"	"	7.32	0.650	"	"	0.650	
Sharp	2P. Maxi.	1502–6	Steel bar	Face mill	18	6	1	35	0.125	6¾	10.8	0.310	0.0173	8.95	8.78	1.030	0.0105	none	1.030	1.36
Dull	"	1502–5	"	10¾ in.	16	6½	"	28	0.125	6¾	11.0	0.394	0.0246	9.10	10.60	0.860	0.0140	A.T.C.	0.760	
Sharp	2P. Maxi.	1500–17	"	Face mill	16	6½	1	40	0.125	6¾	1.44	0.038	0.0024	1.22	1.51	0.810	0.0014	A.T.C.	1.43	2.00
Dull	"	1500–3	"	10 in.	"	6½	"	28	0.125	6¾	9.10	0.218	0.0136	7.51	10.70	0.700	0.0080	none	0.70	

a Find A.T.C. for equivalent speed, feed and depth for spiral mill (see Par. 28) as follows:

1 $\text{A.T.C.} = f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$

2 f = feed per tooth per revolution = feed per rev. divided by no. of teeth in cutter = 0.115 ÷ 13 = 0.0088 in.

3 For a 6-pitch gear cutter, depth d = 0.359 in., whence d/D = 0.359/3 7/16 = 0.104 in.

4 From Table 2 the value of $\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$ when d/D = 0.100 is 0.300, whence—

5 A.T.C. for equivalent spiral mill = 0.0088 × 0.300 = 0.0026 in.

b The value thus obtained must be reduced to obtain true A.T.C. for the form cutter:

1 True A.T.C. for form cutters = A.T.C. for equivalent spiral-mill cut × constant representing ratio of d to W

2 Width of cut W for a 6-pitch cutter is (measured) about 7/16 in. and the standard depth is 0.359 in., whence—

$$\frac{d}{W} = \frac{0.359}{0.437} = 0.82 \text{ approx.}$$

3 From Table 3 the value of the constant for d/W = 0.82 is about 0.50, whence—

4 True A.T.C. = A.T.C. × constant = 0.0026 × 0.50 = 0.0013 in.

c Having found the true A.T.C. as above, we may now read from Fig. 2, at the point of intersection of the line of A.T.C. = 0.0013 with the line for cast iron (semi-steel), the cu. in. per tool hp., which is 1.25 cu. in. approximately.

We would therefore expect 1.25 cu. in. of semi-steel per tool hp. for this cut if the rake on the cutter were 10 deg. and the cutter were half dulled.

d As the rake is actually 0 deg., we must make allowance therefore as per Table 6:

$$1.25 \times (1/1.21) = 1.03 \text{ cu. in. per tool hp-min.}$$

e The amount of metal removed per minute by the above cut will be 3.4 cu. in. for the 5 cutters (= feed per min. × area of cut), assuming that the area for a single cutter is one-half the depth times the circular pitch.

f Since we expect 1.03 cu. in. per hp-min., 3.4 cu. in. per min. will require 3.4/1.03 = 3.3 hp.

g The value thus obtained is for cutters half dulled. For sharp or dull cutters this would be decreased or increased 20 per cent, respectively:

3.3 (1 − 0.20) = 2.65 hp. for newly sharpened cutters
3.3 (1 + 0.20) = 4.12 hp. for dull cutters.

A test cut run with conditions as noted above required 3.26 hp. to the tool with cutters which, while in good condition, had been used before and were partly dulled (No. 4 Max. Test sheet 4004–21).

h To determine the belt hp. from the tool hp., the constants for idle hp. and for efficiency under cut must be known for the machine on which the cut is to be run; this being merely the reverse of the process of finding the tool hp. Having once been determined for any given machine, the relation of output to input (see Fig. 1) for the machine can be reduced to a formula for easy use.

i On the Kempsmith No. 4 Maximiller, for instance, the 4.12 hp. for dull cutters noted in *g* above would be increased as follows:

$$(4.12 \times 1.08) + 0.6 = 5.05 \text{ belt hp. required}$$

While the foregoing method of computing the hp. required for cutting metal may be employed provided a line similar to those in Fig. 2 has been established for the material to be cut, it is much more convenient to use a slide rule in which the data have been incorporated. Such an instrument is described and illustrated in an appendix to the complete paper.

Summary

For milling machines the power economy increases—

a For both slabbing and face-milling cuts:

(1) As the r.p.m. of cutter is decreased, but only if this increases the chip thickness, as in machines having feed rate independent of spindle speed
(2) As the feed per revolution of cutter is increased
(3) As the number of teeth in cutter is decreased (but only if the r.p.m. remains constant, thus increasing the chip thickness)
(4) As the front rake is increased.

b For spiral and slabbing cutters:

(1) As the cutter diameter is decreased
(2) As the depth of cut is increased.

c For face mills:

(1) As the cutter diameter is increased
(2) As the width of cut is decreased
(3) As the corner radius or chamfer is decreased
(4) As the depth of cut is increased, but this only affects power economy when the blades have a rounded or chamfered corner.

For lathes, planers, etc., the power economy increases—

(1) As the feed per turn or per stroke is increased
(2) As the round on tool point is decreased
(3) As the angle of the tool face with direction of feed is decreased
(4) As the cutting rake is increased
(5) As the depth is increased, but this only affects power economy if the end of the tool is rounded

For drills, counterbores, etc., the power economy increases—

(1) As the feed per revolution is increased
(2) As the number of flutes or cutting edges is decreased
(3) As the spiral angle or cutting rake is increased
(4) As the drill is ground with a smaller included angle of point.

While the foregoing points the way to greater power economy, possibilities must in many cases be subordinated to practical considerations. On a miller, for instance, too slow a cutter speed, too few teeth in the cutter and too high a feed, though desirable for cutting efficiency, will cause hammering, and usually the work and jigs will not stand this, even if the machine would do so. In certain cases this can be overcome by using helical mills with large angle of teeth, but not always.

In certain other important details, also, a given set-up may fail in operation even though the computed power is well within the cutting capacity of the machine. Almost any machine may be caused to chatter, or may chatter on certain speeds and feeds, even though the cut is fully within the machine's capacity—in fact, often because the cut is too light or the cutters too sharp to put an initial strain on the supporting structure and take out the slack. More often it is due to synchronized vibrations, which are difficult to avoid for all conditions.

Of two spindle speeds, both may be equally efficient in the transmission of power and have equal belt-hp. capacity, yet the gear leverages and bearing and shaft stresses by which one is obtained may be excellent, while for the other they may be very poor, causing unsatisfactory cuts, chatter vibration, and failure.

As another instance of practical limitations (though this applies only to spiral mills) it might be supposed that more teeth in the cutter would give equal power economy with greater production per unit of time, provided the feed was increased to give the same average thickness of chip, because more chips would be cut per minute by the greater number of teeth. However, not only is there danger of chip interference, but if it be considered that the r.p.m. for a given cutter is limited for any given material, and again that the feed per revolution is limited in most cases by the finish required—which is generally accepted as being determined for spiral mills by revolutions marks and not by tooth marks—it will be seen that a point of r.p.m. and of feed per minute is soon reached where the only way left to increase the average chip thickness and obtain greater economy is to reduce the number of teeth, the only limit in this direction being, as before mentioned, the hammering action of the cutter. As the cut approaches the limit of the machine's power capacity the advantage of few teeth in the spiral mill becomes very marked in its effect upon production.

It is certainly a fact, however, in spite of these limitations, that in many cases a considerable improvement can be made by applying the foregoing laws, and the saving in power, decreased wear on machine, increase in production, etc. which are sure to result will amply repay the effort.

Fiber in Metals

The association of a fibrous structure with strong and tough materials, such as wood and rope, and the corresponding association of crystalline character with weak and brittle materials, such as sugar or bismuth, has produced in the minds of many men, and even of competent engineers, the conception that all really strong and tough materials must be fibrous, and that all crystalline substances are likely to be weak and brittle.

A study of their microstructure, however, shows that all metals in a normal condition—i.e., when not severely cold-worked—are entirely crystalline, and that the minute crystals of which they are composed show no orientation of predominant length. There is, therefore, nothing in the nature of a "fiber" in the metal itself. The individual strips or bars into which a thick bar or plate becomes more or less completely divided by the presence of "slag" bands can never be any the stronger on that account. The metal itself, in fact, possesses no real fiber; its longitudinal strength appears greater than its transverse strength only because in the transverse direction the enclosure bands make their weakening presence felt far more actually than in the longitudinal. Were they entirely eliminated, the metal would be equally strong in all directions, and yet there would be no sign of "fiber."

It would thus seem that the desire for a "fibrous" structure is in essence a mistaken one, and that the cause of the fibrous appearance is in reality a weakness and not an advantage. It is true that under certain bending tests in which the power of the metal to undergo a large amount of plastic bending constitutes the main factor, the "fibrous" material shows higher results. Here the fibrous material gains a spurious advantage from the fact that it is enabled to behave very like a bundle of bars or thin plates rather than as a single piece of material. Owing to the weakness of the slag layers, the various rods and plates are approximately free to slide over one another and a larger amount of bending occurs before fracture takes place. But this is no real gain for practical use. *The Engineer* (London), Nov. 10, 1922, pp. 499–500.

Control of Lumber-Cutting Waste and Production

By CARLE M. BIGELOW,[1] BOSTON, MASS.

Increase in board feet per man-hour and reduction in waste percentage in the cutting department of woodworking plants by means of wage incentive are discussed in the following paper. A differential rate based upon the two factors of production and waste is paid a standard crew.

Eleven steps in the gathering of data required are described. An example of the working out of the payment method is given and its application outlined. The proper planning of cutting orders, standardization of lumber selection and drying, and operational standardization is essential to the method. An example showing results obtained is also given.

THE PURPOSE of this paper is to outline the principles and application of a wage-incentive plan which has been successfully operated to reduce waste and increase production in the cutting departments of furniture, box, toy, auto-body, and general millwork manufacturers.

Little attention has been paid to the reduction of lumber wastage in the past, and even now few concerns are giving the subject the consideration its importance warrants. When we take into account the fact that probably not over 35 per cent of the average tree is actually developed into lumber, and that of this lumber consumed in manufactured wood products from 11 to 60 per cent[2] is wasted, the necessity for conservation is evident.

The essential problem in the cutting of lumber—which differs from the cutting of metal and other materials—is the lack of constancy of the material. Two boards of the same size and supposed quality of lumber may, through the presence of knots, checks, and other defects, have to be utilized in two entirely different manners.

The usual method employed is to send orders for all current products required to the cutting room, where they are got out of the available lumber by a more or less rule-of-thumb, cut-and-try method.

After a number of years' experience in the industry, it is the author's opinion that it is absolutely impossible to utilize lumber economically in this manner; that in spite of the very variable nature of the lumber, the only solution for economical cutting is a carefully devised scientific method. The first step in the development of such a method is the collection of the following data:

1 *Production Budget.* The entire production (manufacturing budget) for a manufacturing period should be carefully estimated. This period should be never less than three months and if it is possible to estimate a year's production fairly well, it is better to make it up for this period.

2 *Parts List.* Analyze this production into a table of all parts required, grouping together all those that are interchangeable.

3 *Parts Dimensions.* Rough-dimension into length, width, and thickness the classification of parts given above.

4 *Cutting Bills.* After careful consultation with and advice from the practical management personnel, make up from this list average cutting bills for kiln loads of lumber so assorted that practically all the various usual lengths and widths may be utilized by each cutting and still satisfy the average flow of orders.

5 *Part-Stock Control.* Establish a careful physical control and perpetual-inventory method over any accumulation of part stock in order that in making up cuttings such stock may not be unduly increased over the requirements shown by the manufacturing budget.

6 *Operational Standardization.* Study and standardize each machine and manual operation in the cutting department, determining definitely the proper method, feeds, speeds, etc., and man-hour production for maximum first-quality production of the manufacturing budget.

7 *Standard Crew.* Considering the previously mentioned standards and the manufacturing budget, establish a normal working crew for the department with stated base rates of pay.

In one plant where this method was applied the original crew numbered 37 and were paid $884.80 weekly as follows:

2 supervisors	$ 59.80
22 operators	558.50
11 helpers	217.50
1 knifeman	30.00
1 sweeper	19.00
37	$884.80

The standard crew of 20 received $505 as follows:

1 foreman	$ 42.50
1 assistant foreman	32.50
1 dispatch clerk	25.00
9 operators at $26 each	234.00
6 helpers at $20 each	120.00
1 knifeman	32.00
1 sweeper	19.00
20	$505.00

8 *Board-Foot-Hours Standard.* Determine the average board footage per operative-hour required by the above-mentioned standard crew to produce the manufacturing budget.

9 *Lumber Assortment.* The general quality and sizes of lumber to be purchased should be studied to be sure that the best material for the product is available. In this connection it should be seen to that the proper thicknesses of lumber are on hand to avoid any wastage through the use of improper sizes, a common cause of waste.

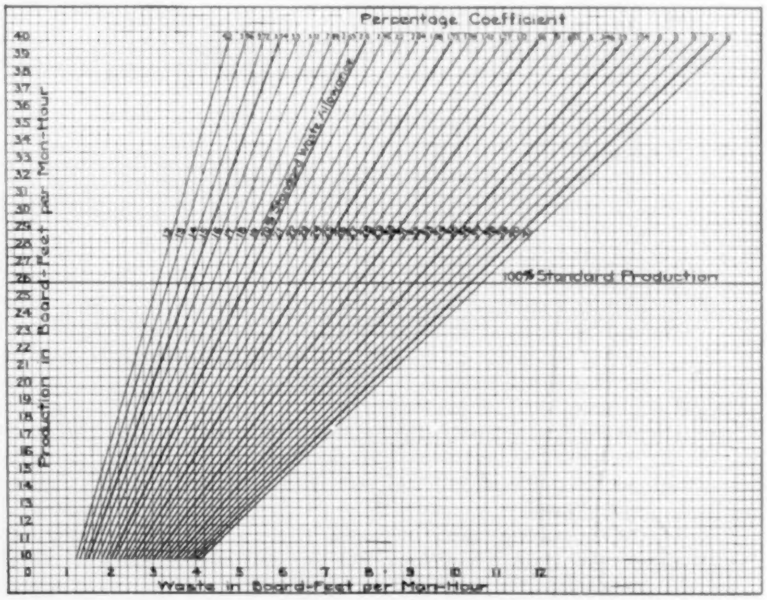


Fig. 1 Production-Waste Ratio Chart

(The percentage coefficient multiplied by the number of board feet produced per man-hour gives the bonus percentage for the hours worked.)

The assortment of No. 1 common, of 1s and 2s, etc., to be purchased must be based upon purely local requirements and should be proved by a series of lengthy test runs of the various grades. Such a classification developed in a certain high-grade cabinet plant was as follows:

Quartered White Oak. 1s and 2s specially selected for light color, all well-figured stock, free from mineral streaks, coarse grain, worm holes, pink flakes and sap. All stock to be well air-dried and the moisture content not to exceed 20 per cent.

Poplar. No. 1 common and selects, free from dark mineral streaks and black stain.

[1] Chief Engineer, Cooley & Marvin Co. Mem. Am.Soc.M.E.

[2] This wide variation in wastage depends upon lumber variety and quality, product, and cutting methods.

Contributed by the Forest Products Division for presentation at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly Abridged. All papers are subject to revision.

Mahogany. 1s and 2s African, all ribbony-figured stock; end-grain stock not allowed.
Chestnut. No. 1 common and better, sound wormy.
Quartered Red Gum. No. 1 common and selects.
Sap Birch. No. 1 common and selects. On $^5/_4$-in. birch 10 per cent of 1s and 2s and 10 per cent of No. 2 common acceptable where necessary.
Crating Lumber. 1 in. by 4 in. No. 2 common and better short-leaf yellow pine D2S to $^{11}/_{16}$-in. square-edge soft-texture stock, random 10- to 16-ft. lengths, air-dried.

10 *Drying.* The kiln equipment and methods of drying should be carefully studied and standardized. Improper drying methods often render any attempts at waste reduction in the factory abortive.

11 *Waste Limits.* By test runs, knowledge based upon experience, and direct calculation, determine fair waste limits for the various cutting schedules, using lumber of the grades selected.

DEVISING AND INSTALLING THE PLAN

With the data available from the preceding eleven steps, we now have three major requirements:

1 Devise an incentive wage-payment plan
2 Inaugurate proper planning of cutting
3 Install the payment plan.

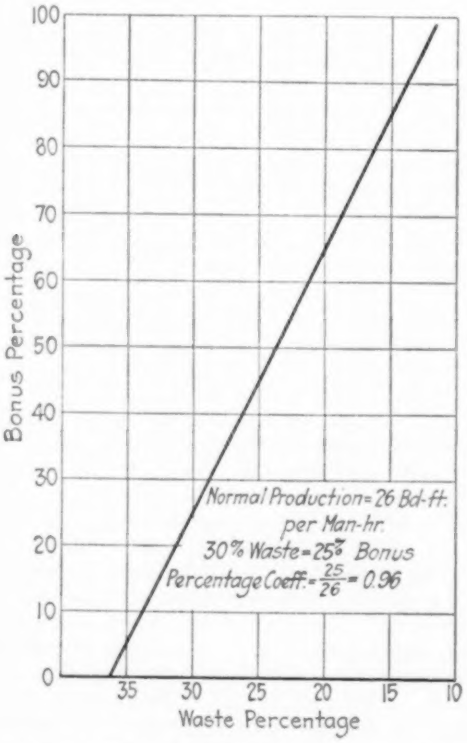


Fig. 2 GRAPH OF BONUS INCENTIVE FOR WASTE REDUCTION AT POINT OF NORMAL PRODUCTION

Devising the Incentive Payment Plan. An incentive wage-payment plan for a cutting department must control both production and waste. The development of such a plan will be illustrated by an example, the plant in which it was applied being one manufacturing a very high grade of stock and special office and library furnishings and equipment.

The range of production per man-hour for the standard crew was determined to be from 11 to 30 ft. B. M., standard at 26 ft. The waste range was from 36 per cent down to 15 per cent, standard at 20 per cent.

The first step is to chart the relations between board-feet-per-hour production and waste, for a range of waste percentages somewhat wider than the standard Such a chart is shown in Fig. 1. The percentage coefficients at the top of the chart are determined as follows:

A graph of bonus percentages for waste eliminations is plotted as shown in Fig. 2. The percentages of bonus used are determined by experience, and are set to produce the necessary incentive. The standard board footage per hour on Fig. 1 is 26. The waste bonus shown in Fig. 2 applies specifically to this production, therefore the percentage bonus allowed for any percentage of waste divided by 26 gives a coefficient which if multiplied by any board-foot production, gives an excellent differential bonus percentage for both production and waste.

For example: 30 per cent waste on Fig. 1 is allowed 25 per cent bonus; whence $25/26 = 0.96 =$ coefficient for 30 per cent waste and the bonus for a production of 30 ft. B. M. hr. $= 30 \times 0.96 = 28.8$ (29) per cent; for a production of 25 ft. B. M. hr. $= 25 \times 0.96 = 24$ per cent, etc.

Fig. 4 is then calculated from the coefficients determined on Fig. 1, and gives the direct bonus percentage for each combination of waste and production within the standard range.

Inauguration of Planning of Cutting. A complete list of active dimension sizes, arranged according to woods, thicknesses, lengths, widths, and net board footage of each block, with adjacent columns showing clear sides and edges required, color requirements and, in the case of quartered oak, quartering-figure requirements, should be used by the planning department, and the superintendent and foreman of the lumber-cutting department in their coördinated efforts to put through economical dimension schedules of each kiln load of lumber ordered in.

The use of the standard cutting lists to make up a dimension-cutting schedule is as follows:

In the layout of the production orders in the planning department

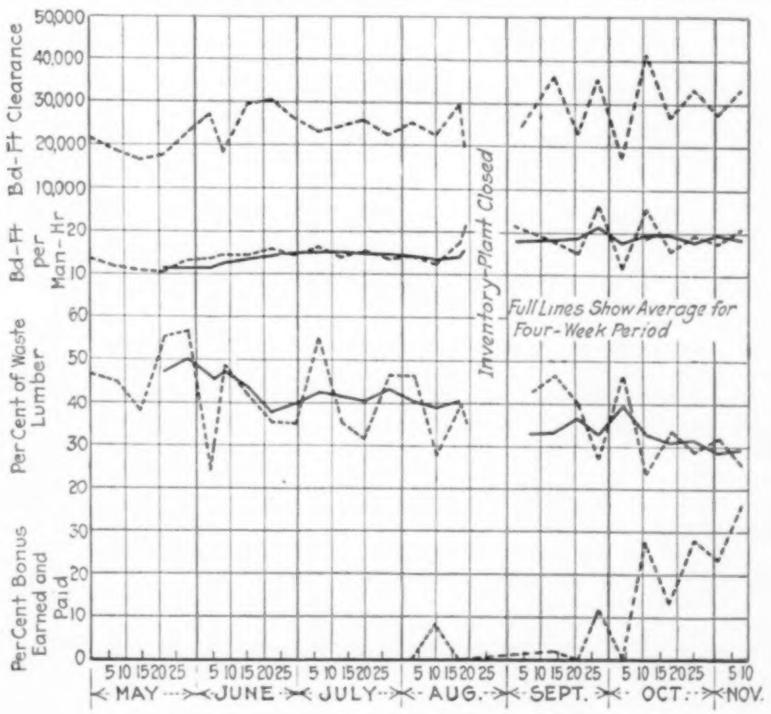


FIG. 3 SIX MONTHS' RESULTS OF PLAN OUTLINED

they should be made into groups comprising the same or similar dimension stock of sufficient volume to enable the issuance of an advantageous manufacturing order. The head of the planning department should supervise the listing from these orders of quantities of dimension block sizes, to fill the orders and make up a dressed dimension-cutting schedule for at least a week ahead.

Continuous close touch should be maintained by the planning department with the part-stock inventory at all times in order that manufacturing orders and part-stock requisitions may be supplemented and filled out to an advantageous program in making out a dressed dimension-cutting schedule. Additional manufacturing orders should be issued for enough additional board footage of dimension stock in order that there will be balanced economy in the cutting, since some catalog units and their parts usually permit more advantageous dimensioning than others, and it is desirable to equalize the advantage week by week as much as possible for the lowest final average.

Installation of the Wage-Payment Plan. With the proper assortment of carefully dried lumber available and the cutting orders planned for widest possible range of sizes under the order require-

ments, the plan is explained to the personnel of the cutting department. During the investigation, records of intake, clearance and waste should have been installed. For several weeks a trained woodworking engineer should work continuously in the department, instructing and encouraging the workers.

For each pay period the net clearance of product from the department divided by the total number of hours worked by the standard crew gives the board-foot-per-hour production.

Production in Board-Feet per Man-Hour

Waste Percentage	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
36	0	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	5
35	0	3	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7
34	0	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10
33	0	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
32	0	7	8	9	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20
31	0	9	10	11	11	12	13	14	15	15	16	17	18	19	19	20	21	22	23	24	24
30	0	11	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
29	0	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30	31	32	34
28	0	14	15	17	18	19	20	22	23	24	25	27	28	29	31	32	33	34	36	37	38
27	0	16	17	18	20	21	23	24	26	27	28	30	31	33	34	35	37	38	40	41	43
26	0	17	19	21	22	24	25	27	28	30	32	33	35	36	38	40	41	43	44	46	47
25	0	19	21	22	24	26	28	29	31	33	35	36	38	40	42	43	45	47	48	50	52
24	0	21	23	24	26	28	30	32	34	36	38	40	41	43	45	47	49	51	53	55	56
23	0	22	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61
22	0	24	26	29	31	33	35	37	40	42	44	46	48	51	53	55	57	59	62	64	66
21	0	26	28	31	33	35	38	40	42	45	47	49	52	54	56	59	61	63	66	68	71
20	0	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	65	68	70	73	75
19	0	30	32	35	38	40	43	46	48	51	54	57	59	62	65	67	70	73	75	78	81
18	0	31	35	38	40	43	46	49	52	55	58	61	64	67	69	72	75	78	81	84	86
17	0	34	38	41	44	47	50	53	56	59	62	65	69	71	75	78	81	84	87	91	94
16	0	36	40	43	46	50	53	56	59	63	66	69	73	76	79	83	86	89	93	96	99
15	0	39	43	46	50	53	57	60	64	67	71	74	78	82	85	89	92	96	99	106	109

Standard Waste

Standard Production

Fig. 4 Bonus Percentages for Standard Range of Waste and Production

Net intake less net clearance divided by net intake gives the waste percentage.

Fig. 3 shows the results obtained in six months in the plant at which the charts shown in Figs. 1, 2 and 4 were used. These figures were recorded in 1921, therefore over a year has elapsed since the results were obtained. During this past year the standard condition of 26 ft. B. M. per hr. and 20 per cent waste has been bettered several times.

Fig. 4 shows the bonus percentage of standard wages, which, added to the standard wages, gives the total pay.

The Dollars and Cents Results

Suppose—and these are average conditions—that a plant is operating with a clearance of 12 ft. B. M. per man-hour, cutting wages of 50 cents an hour, and 45 per cent waste. The application of the bonus rate shown in Fig. 4 should result in the following saving for each 1,000,000 ft. B. M. of lumber used if the standard waste and standard production are attained:

Labor:
- Original Cost:
  - Hourly wages = \$0.50
  - Hourly production = 12 ft. B. M.
  - \$0.50/12 = \$0.042 per ft. B. M.
- Resulting Cost:
  - Hourly wages = \$0.50 + 65 per cent bonus = \$0.83
  - Hourly production = 26 ft. B. M.
  - \$0.83/26 = \$0.032 per ft. B. M.
- Saving per ft. B. M.:
  - \$0.042 − \$0.032 = \$0.01
- Saving per Million ft. B. M.:
  - 1,000,000 × \$0.01 = \$10,000

Material:
- Original waste = 45 per cent
- Resulting waste = 20 per cent
- Lumber saving = 25 per cent
- Lumber cost 1,000,000 ft. (\$70 per M.) = \$70,000
- 25 per cent of \$70,000 = \$17,500

Total Saving Per Million Ft. B. M.:
- \$10,000 (labor) + \$17,500 (material) = \$27,500

In a plant using 500,000 ft. of lumber a year, the above saving will represent an appreciable reduction in manufacturing cost.

TESTS OF TYPE W STERLING BOILER AT THE CONNORS CREEK POWER HOUSE

(Continued from page 31)

$$\text{For floating bank, lb. coal} = 8600 + 105x$$
$$\text{For dead bank, lb. coal} = 8000 + 280x$$

where x = number of hours banked. These equations give a greater amount of coal for a floating bank than for a dead bank for periods of less than four hours; but under actual conditions there is practically no difference between the two kinds of banks for the first portion of a banking period, so the equations are meant to apply only to banking periods in excess of four hours.

General. At the present writing seventeen boilers have been rebaffled according to arrangement "B," modified slightly in the arrangement of the cross-baffle at the top of the front baffle. The vertical baffle has been shortened about six inches and the cross-baffle at the top inclined upward at about 35 deg. from the front baffle. The results being obtained indicate that the superheated-steam temperature has been increased fully 50 deg. fahr. over that obtained with the original baffle, and that there is a decided improvement in the overall efficiency.

A study of the heat absorbed in the different passes of the boiler indicated that a rearrangement of tubes would be beneficial. This possibility was studied by the engineers of the Babcock and Wilcox Company and The Detroit Edison Company, with the result that the new boilers recently installed at the Marysville power house have in cross-section but five tubes between the upper center drum and each mud drum and ten tubes between each mud drum and the upper drum directly above. The boiler is baffled similarly to arrangement "B," except that there are two vertical baffles in each rear bank which direct the gases in three vertical passes after they leave the superheater pass. Economy results are not yet available, but it is believed that a decided decrease in the stack-gas temperatures will be realized.

Discussion

Dr. D. S. Jacobus,[1] said that it gave him great pleasure to discuss the paper, as it brought back recollections of a test that he had made at the Del Ray plant about ten years ago, and of the many courtesies and kindnesses extended to him at that time.

His results, Dr. Jacobus said, were consistent with those obtained by Mr. Thompson. William Kent, in discussing his paper, had pointed out that Dr. Jacobus' tests gave the highest efficiencies at high as well as low rates of driving ever obtained from coal having over 25 per cent of volatile matter, and it was indeed gratifying to note that the results were substantiated and that Mr. Thompson had secured somewhat higher efficiencies than those found in his tests. The efficiencies secured by Mr. Thompson at the lower ratings with the baffles arranged in the same way as in the Del Ray tests were the same as those which Dr. Jacobus had obtained. At the higher ratings Mr. Thompson's results were about 2 per cent higher than his, this difference, as shown by the heat balances, being due mainly to there having been a lesser loss through the carbon in the ashes in Mr. Thompson's tests. When corrected for the differences in the ash pit losses, however, the results agreed within one per cent, which was remarkably close when one considered the error that might be involved in estimating the condition of the fires at the beginning and end of a test with about 15 tons of coal on the grates.

The tests clearly indicated the advantage of changing the baffles. In addition to obtaining higher efficiencies the superheat was increased in the arrangement adopted for use and as a higher superheat could be made good use of, this was also an advantage.

He had visited the plant when Mr. Thompson's tests were in progress and could certify to the fact that they had been conducted in a most exact and scientific way. He had held up these tests on several occasions as an example of the sort of industrial research that should be encouraged by Engineering Foundation and the National Research Council, as they were a direct benefit in the problem of the conservation of fuel and to the engineer at large.

[1] Advisory engineer, Babcock & Wilcox Co., New York, N. Y. Mem. Am.Soc.M.E.

The Torsional Strength of Bars

By CONSTANTIN WEBER

MATHEMATICAL treatment of the torsional strength of bars, giving a general solution of the problem together with precise solutions for certain cases and approximate solution for others. The article was briefly summarized in the November, 1922, issue of MECHANICAL ENGINEERING, but so many inquiries as to details have been received that it has been decided to publish a more complete abstract.

In the middle of the 19th century Saint-Venant developed a general differential equation for the torsion of bars; he also found exact solutions for a limited number of cross-sections. In practice, however, bars are encountered of cross-sections vastly different from those treated by Saint-Venant. Foeppl gave exact solutions for a certain number of these, in particular for thin-walled rolled shapes composed of long rectangles, but there are still a number of sections of considerable interest from a practical point of view which remain unsolved. The present article is an abstract of a research monograph (Forschungsarbeit Heft 249) published by the German Society of Engineers. It comprises fundamental equations for the torsional strength of bars, the more important exact and approximate solutions for various shapes, the influence of normal stresses in the axial direction at considerable twists, and the curvature of certain cross-sections. Among other things, several errors in engineering handbooks are pointed out.

General Solution

If a couple acts on a prismatic bar made of a material which is isotropic and behaves in accordance with Hooke's law, and if this couple acts at right angles to the axis of the bar, the bar becomes subject to torsion, the moment of torsion being, say, M cm-kg. Let now axes of reference x, y and z be passed through the body as shown in Fig. 1, so that the z-axis coincides with the axis of torsion.

The longitudinal fibers lying in the z-axis remains straight, while all the other fibers assume helical shapes about this axis. There are therefore shear stresses τ in the cross-sections of the bar which may be resolved into shear stresses τ_{xz} in the y-direction and τ_{yz} in the x-direction. Simultaneously, however, these shear stresses appear in the z-direction in longitudinal sections parallel to the y-z or x-y planes. The condition that all the forces acting on a particle in the z-direction should be in equilibrium gives—

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} = 0 \quad\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

This equation is satisfied through—

$$\tau_{xz} = \frac{\partial f}{\partial y},\quad \tau_{yz} = -\frac{\partial f}{\partial x} \quad\ldots\ldots\ldots\ldots\ldots [2]$$

in which $\frac{\partial f}{\partial x}$ and $\frac{\partial f}{\partial y}$ are partial derivatives of a function—

$$f(x,y) = K \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

For each value of K a closed line is obtained on the cross-section and the resultant shear stress coincides at every point with a tangent to this line (Fig. 2). Equation [3] is therefore the equation of the family of lines of shear.

Two contiguous lines of stress corresponding to the values of K and $K + dK$ delimit the closed strip of variable width dn which corresponds in the body to a tubular lamination (Figs. 3 and 4).

Since there are no forces acting on the walls of this tubular lamination it may be separated from the rest of the body. Referring to Fig. 4, the area ABB_1A_1 of this tubular lamination (of length unity) is acted on by a constant longitudinal shear force—

$$dK = \tau dn \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

If we integrate the force dK we shall obtain for the inner shear line the value K_i and for the outer limit line the value K_a. The entire longitudinal shear force acting in this cross-section is then $K_a - K_i$.

The cross-sections of the bar originally plane become curved. The points on any line parallel to the x-axis are displaced in the z-direction. At the point xy the curved line forms with the original position of the line the angle—

$$\gamma_x = -\delta y + \frac{\tau_{xz}}{G} \quad\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

where G is the modulus of rigidity and δ the angle of torsion in a given length. Correspondingly the equation holds good for points lying on the lines originally parallel to the y-axis:

$$\gamma_y = \delta x + \frac{\tau_{yz}}{G} \quad\ldots\ldots\ldots\ldots\ldots\ldots [5a]$$

In order that the internal arrangement of all the molecules constituting the body remain unchanged, the following equation must hold good:

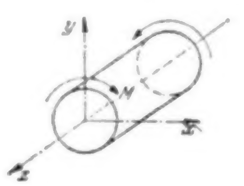


Fig. 1 Axes of Reference in a Bar under Torsion

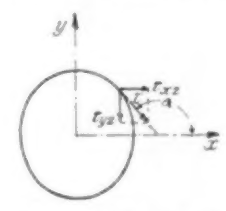


Fig. 2 Line of Shear

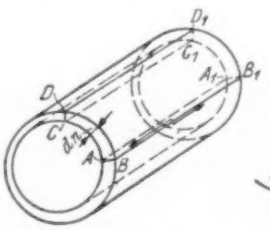


Fig. 3

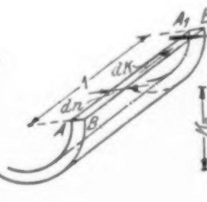


Fig. 4

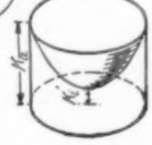


Fig. 5

Figs. 3 and 4 Longitudinal Shear in a Tubular Lamination

Fig. 5 Graphic Representation of the Moment of Torsion in a Bar

$$\frac{\partial \gamma_x}{\partial y} = \frac{\partial \gamma_y}{\partial x}$$

From this may be derived the equation of internal structure, namely,

$$\frac{\partial \tau_{xz}}{\partial y} - \frac{\partial \tau_{yz}}{\partial x} = 2G\delta \quad\ldots\ldots\ldots\ldots\ldots [6]$$

Equations [2] and [6] give the differential equation for the family of lines of shear, or—

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = 2G\delta \quad\ldots\ldots\ldots\ldots\ldots [7]$$

For the entire cross-section the equation for the family of lines of shear $f(x,y) = K$ must satisfy the differential equation [7], must always remain within the confines of the given cross-section, and must give the outer limit for the value $K = K_a$. In addition, for the case of a ring-shaped cross-section $f(x,y) = K_i$ must give the inside limit line, and the relation—

$$\int \tau dt = 2G\delta F \quad\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

must be satisfied as applying to the shear line surrounding the hole.

In this equation dt is the longitudinal differential of the corresponding lines of shear and F is the enclosed area. The integral extends over the closed line of shear.

The moment is obtained by integrating $y\tau_x df + x\tau_y df$ over the entire cross-section—

$$M = 2K_aF_a - 2\int\int f dx dy \qquad [9]$$

If over each point of the cross-section be plotted the heights $K = f(x, y)$, the body shown in Fig. 5 will be obtained. The moment is represented by double the volume of the funnel-shaped depression. In the case of ring-shaped cross-sections a truncated funnel is correspondingly obtained, but in both cases the moment may be expressed as follows:

$$M = 2\int_{K_i}^{K_a} F dK \qquad [10]$$

Where F is the area within the line of shear corresponding to the variable K.

The general solution of the differential equation [7] is given in

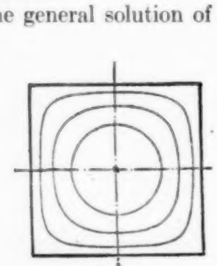


FIG. 6

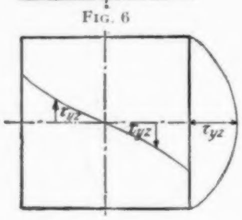


FIG. 7

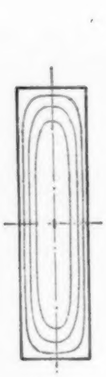


FIG. 8

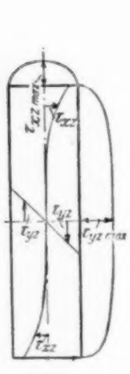


FIG. 9

FIGS. 6 AND 7 LINES OF SHEAR AND STRESSES IN A SQUARE CROSS-SECTION
FIGS. 8 AND 9 LINES OF SHEAR AND STRESSES IN A RECTANGULAR CROSS-SECTION

$$f(x,y) = 2G\delta\left(\frac{x^2}{4} + \frac{y^2}{4}\right) + g_1(y + ix) + g_2(y - ix) = K \qquad [11]$$

and the functions g_1 and g_2 must be so selected that the imaginary members will disappear. As examples of functions of $g_1(y + ix) + g_2(y - ix)$, the author cites the following:

Rational Algebraic Functions:

$$\tfrac{1}{2}[(y + ix) + (y - ix)] = y$$
$$\tfrac{1}{2}[(y + ix)^2 + (y - ix)^2] = y^2 - x^2$$
$$\tfrac{1}{2}[(y + ix)^3 + (y - ix)^3] = y^3 - 3yx^2$$

Trigonometric Hyperbolic Functions:

$$\begin{aligned}\tfrac{1}{2}[\cos a\,(y + ix) + \cos a\,(y - ix)] &= \cos ay \cosh ax \\ &= \cos ax \cosh ay \\ &= \sin ay \sinh ax \\ &= \sin ax \sinh ay\end{aligned}$$

In Polar Coördinates:

$$g_1(y + ix) + g_2(y - ix) = r^n \cos n\varphi$$

Here n may be any positive or negative number, fractional or integral.

EXACT SOLUTIONS FOR SPECIAL CASES

Under this head the author discusses the solutions for a circular and elliptical cross-sections, an equilateral-triangle cross-section, and a rectangular cross-section. Only this latter will be presented here.

The author considers the case of a bar of rectangular cross-section of width a and height $h = na$ $(n \geqq 1)$. The solution for the family of lines of shear is obtained by the use of a series of trigonometric hyperbolic terms:

$$2G\delta\left(\frac{x^2}{4} + \frac{y^2}{4}\right) + 2G\delta\left(\frac{x^2}{4} - \frac{y^2}{4}\right)$$

$$+ G\delta a^2 \sum_{k=1}^{k=\infty} (-1)^{\frac{k-1}{2}} \frac{\cosh\left(k\dfrac{\pi}{2}\dfrac{y}{{}^1\!/_2 a}\right)\cos\left(k\dfrac{\pi}{2}\dfrac{x}{{}^1\!/_2 a}\right)}{\left(\dfrac{\pi}{2}\right)^3 k^3 \cosh nk\dfrac{\pi}{2}}$$

$$+ c_1 = K$$

$$(k = 1, 3, 5 \ldots)$$

From this the moments and stresses may be calculated. Figs. 6 to 9 show the lines of shear and the distribution of stresses for a square and a rectangle with $n = 4$. The relation between the stresses, the moment and the dimensions of the cross-section may be expressed by means of auxiliary values ψ_1, ψ_2, etc. by the following equations:

$$\tau_{yz\,\max} = \tau_{\max} = \psi_1 G\delta a$$

Here $\tau_{\max}$ occurs at the middle of the long side. In long rectangles with $n>4$ the stress found close to the ends is zero)

$$\tau_{xz\,\max} = \psi_2 G\delta a$$

(This stress occurs at the middle of the short side)

$$M = n\psi_3 G\delta a^4$$

$$M = \frac{\tau_{\max} a^2 h}{\psi_4}$$

$$A = \psi_5 \frac{\tau^2_{\max} V}{G}$$

Here A is the work of deformation and V the volume of the bar. The longitudinal stress measured from the middle of the cross-section of the edge is—

$$K_a = \psi_6 G\delta a^2$$

The values ψ_1 to ψ_6 are presented in Table 1.

TABLE 1 VALUES OF ψ

n =	1	1.5	2	3	4	6	8	10	∞
ψ_1 =	0.6753	0.8476	0.9300	0.9854	0.9970	0.9999	~1	~1	1
ψ_2 =	0.6753	0.7279	0.7395	0.7423	0.7423	0.7425	0.7425	0.7425	0.7425
ψ_3 =	0.1404	0.1957	0.2286	0.2633	0.2808	0.2982	0.3070	0.3123	0.3333
ψ_4 =	4.81	4.33	4.07	3.74	3.55	3.35	3.26	3.20	3.00
ψ_5 =	0.1539	0.1362	0.1318	0.1357	0.1412	0.1491	0.1535	0.1562	0.1667
ψ_6 =	0.1472	0.2015	0.2277	0.2454	0.2491	0.2500	0.2500	0.2500	0.2500

FIG. 10 COMPARISON OF THE VALUES OF ψ_1 AS OBTAINED BY THE AUTHOR AND AS GIVEN IN THE HUTTE ENGINEERIMG HANDBOOK

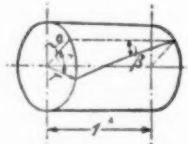


FIG. 11 TORSIONAL DEFORMATION OF A BAR

For the most important of these values, namely, ψ_1, ψ_3 and ψ_4, the following approximate equations can be used:

$$\psi'_1 = 1 - \frac{0.65}{1 + n^3} \text{ (error} < 0.8 \text{ per cent)}$$

$$n\psi'_3 = \frac{1}{3}\left(n - 0.630 + \frac{0.052}{n^4}\right) \text{ (error} < 0.5 \text{ per cent)}$$

$$n\psi'_4 = 3 + \frac{1.8}{n} \text{ (maximum error, approximately 4 per cent)}$$

The author plots the values from the above table in a series of curves such as, for example, Fig. 10, and side by side in broken lines plots from the Hütte Handbook (22nd German edition, pp. 569–571) the values commonly accepted. It is of interest to note how far apart the two are. The values for A in the above formula in Hütte (same edition, pp. 597–598) appear to be likewise wrong.

APPROXIMATE SOLUTIONS

A series of approximate solutions are given covering various ring-shaped cross-sections, strip-like sections and composite sections. In arriving at these solutions the author uses the differential equation [7] for the family of lines of shear and by transforming it into one expressed in polar coördinates he obtains—

$$\frac{d\tau}{ds} + \frac{\tau}{\rho} = 2G\delta \qquad [12]$$

where ρ is the radius of curvature of the line of shear at a given point,

τ the stress, and $d\tau/ds$ the differential of the latter normal to the direction of stress.

Deformation Resulting from Torsion

Axis of Rotation. As a result of torsion longitudinal fibers of the bar assume a helical shape about the axis of rotation. In the case of small torsions such as occur ordinarily, the angle of inclination β of the helices (Fig. 11) to the axis is so small that for a finite length of bar each of these helices does not noticeably differ from a straight line and therefore each fiber may be considered as an axis of rotation.

In the case of greater rates of torsion the angle β of the outer fibers is greater and they can no longer be considered as lying in a straight line. In this case a given longitudinal fiber becomes the axis of twist, and a point in the cross-section of the bar the center of twist. Because of their stretch the outer fibers are subjected to tensile stresses, and if no force is acting on the bar in the longitudinal direction the fibers in the neighborhood of the axis of rotation are under compression. The center of torsion is at the point where no bending moment is produced by the longitudinal stresses. In polysymmetrical sections the center of torsion coincides with the center of the geometric figure, but this is not the case with non-symmetrical or simple symmetrical cross-sections. The normal stresses are expressed by—

$$\sigma_z = \frac{1}{2} E\delta^2 \left(r^2 - \frac{J_p}{F} \right)$$

where J_p is the polar moment of inertia with reference to the center of rotation, F the area of cross-section of the bar, and r the distance from the center of rotation. The stresses σ_z increase as the

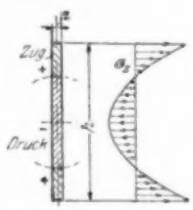


Fig. 12

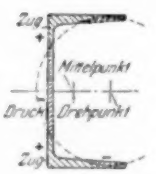


Fig. 13

Figs. 12 and 13 Normal Stresses at Twists of Considerable Magnitude

(*Zug* = tension; *druck* = pressure; *mittelpunkt* = center; *drehpunkt* = center of rotation.)

square of δ, while the stresses τ vary directly as δ. For small values of δ, τ is the most important stress and it is only when δ becomes large that σ_z takes on significance. Figs. 12 and 13 show the distribution of normal stresses in a long rectangular cross-section and in a channel cross-section. In the latter it is clear that the center of rotation does not coincide with the center of gravity. From this it follows that the statement in the Hütte Handbook (22nd German edition, p. 568), namely, "the center of the arc of torsion, i.e., the point on the cross-section which is not subject to displacement by the moment and in which, therefore, the shear stress is equal to zero, is the center of gravity," does not apply to all cases. Neither does the center of rotation always coincide with the center of gravity, nor is the stress τ at the center of rotation or center of gravity equal to zero.

In the center of rectangular sections with large values of the ratio n between the sides, $J_p \sim J_y$ and $p \sim y$. Because of this,

$$\sigma_z = \frac{1}{2} E\delta^2 \left((y^2 - \frac{1}{12} h^2 \right);$$

$$\sigma_{z\,\max} = \frac{1}{12} E\delta^2 h^2; \; \sigma_{z\,\min} = -\frac{1}{24} E\delta^2 h^2$$

If $\tau \gtrless 1000$ kg. per sq. cm., $E = 2{,}150\,000$ kg. per sq. cm., and $G = 83{,}000$ kg. per sq. cm., the normal stress ψ_z has to be taken into consideration when $n > 40$ or thereabouts. Through the stress σ_z is transmitted the additional moment of torsion M_z. In the minute area of cross-section df distant r from the center of rotation, the force acting thereon is $\sigma_z df$. As the fiber forms at this point the angle $\beta = \delta r$ with the axis of rotation, we have a partial force $\beta\sigma_z df$ acting on the plane of the cross-section and creating a moment $r\,\beta\sigma_z df$. For the entire section the moment is—

$$M_z = \int r\beta\sigma_z df = \frac{1}{360} E\delta^3 n^5 a^6$$

where n is the ratio of the lengths of the sides of the rectangle and a the width of the rectangle. The moment transmitted by the shear stress and the normal stress is—

$$M_s = \frac{1}{360} E\delta^3 n^5 a^6 + \frac{1}{3} G\delta n a^4$$

The deformation A_z due to the normal stress is for the length of bar l,

$$A_z = \frac{1}{4} M_z \delta l$$

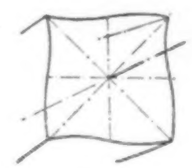


Fig. 14

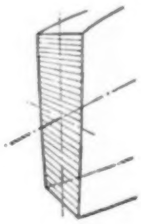


Fig. 15

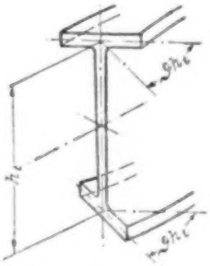


Fig. 16

Figs. 14–16 Curvature of Square, Rectangular, and I-Beam Cross-Sections

while the work of deformation due to the shear stress is determined by the usual formula—

$$A = \frac{1}{2} M_z \delta l$$

Curvature of the Cross-Section

Because of the presence of the moment of torsion the originally plane cross-sections of the bar become curved, only circular and circular ring cross-sections remaining plane. In symmetrical cross-sections the lines of symmetry remain straight. Thus, Figs. 14 and 15 show respectively the curvature of a square and of a long rectangular cross-section. The width lines of this cross-section remain at all points approximately at right angles to the longitudinal fibers of the bar which are here twisted to helices. Fig. 16 shows the curvature of an I-beam cross-section.

Some of the conclusions at which the author arrives are as follows: A homogeneous, elastic prismatic bar is stressed by a couple the plane of which is normal to the axis of the bar. This leads to a twist of two cross-sections of the bar located at a distance of 1 cm. apart through a relative angle δ.

The shear stress τ and the moment of torsion M are functions of and may be expressed by the dimensions of the cross-sections, the modulus of rigidity G and the angle δ in accordance with the formulas given in the November, 1922, issue of Mechanical Engineering on pp. 738–739. The functional relation between $\tau_{\max}$ and M depends on the distance for which δ is measured.

The original article gives a table containing expressions for the moment of torsion and stresses in bars of various cross-sections—twenty in all. This table was published in the November, 1922, issue of Mechanical Engineering, pp. 738–739, and is therefore not reprinted here.

Attention is here called to the fact that a correction should be made in this table: namely, the last formula in the column "Moments for Cross-Sections," No. 16, should read—

$$l_{t2} = l_2 - 1.67s_f + 1.76s_s.$$

(*Zeitschrift des Vereines deutscher Ingenieure*, vol. 66, nos. 31–32, Aug. 31, 1922, pp. 764–769, 35 figs. and an illustrated table, *tpA*)

Short Abstracts of the Month

AIR MACHINERY

Some Elements in Air Compression, W. Carter. A paper chiefly of a practical character discussing the essentials of construction of the air compressor and method of using it. Only a few features will be referred to here.

In discussing the various methods of drive, in particular, belt drive on close centers, the author calls attention to a recent development, namely, an arrangement involving the use of a floating idler pulley and a very slack belt. The weight of the idler takes up the slack of the belt and increases the arc of contact on the driving and driven pulleys so that the full power is transmitted without any undue strain on the bearings or on the belt itself.

A very modern development is the direct-connected electric-driven air compressor with the rotor of a synchronous motor mounted directed on the compressor shaft. This construction is not applicable to smaller units than about 700-cu-ft., 100-lb.-pressure compressors, because the cost for direct connected synchronous motors of small power becomes excessive. On moderate- and large-sized machines, however, this design affords the very highest possible economy. Recent improvements in air-valve movements and in air-cylinder design which permit much higher piston speeds than ever before were considered practical, have contributed to the success of the direct-connected compressor unit of this design. Unless the valve and port areas are very large, the compression efficiency is so greatly reduced at the customary speeds as to offset the advantages of compactness. The choice of a direct-connected motor-driven air compressor should therefore be determined by an investigation as to whether the compressor had been specially designed for this method of drive. (*Canadian Railway Club*, vol. 21, no. 7, Oct., 1922, pp. 19–39, *p*)

Multi-Stage Fan-Type Blower. Description of blowers of a new type made by the Syracuse Industrial Gas Co., Syracuse, N. Y. As shown in Fig. 1, the blower is essentially composed of three machines all located within the same casing. The air or

Fig. 1 Multi-Stage Fan-Type High-Pressure Blower

gas passes from fan to fan, each fan boosting the pressure in the same way as if it were a single-stage machine. The machines now built give pressures up to 2 lb. in small units. (*Forging and Heat Treating*, vol. 8, no. 10, Oct., 1922, pp. 484–485, 2 figs., *d*)

ENGINEERING MATERIALS (See also Special Processes)

The Influence of Phosphorus on Brass, A. Portevin. Tests were made on two series of brasses with an increasing proportion of phosphorus added in the form of phosphor copper containing 10 per cent of that element. The first series averaged 68 per cent copper and the second 58 per cent. Tests were made from both series cast in sand and in chills, the latter in the form of round brass $1^3/_4$ in. in diameter.

From these tests it was found that the mechanical properties are not sensibly affected as long as the phosphorus content remains below 0.05 per cent. When the proportion of phosphorus exceeds 0.5 per cent, a rapid fall in ductility and elongation takes place. (From the two tables given in the article it would appear that for some reason or other the phosphorus content was varied by big jumps. Thus, in one series of sand-cast tests the phosphorus content varied from nothing to 0.077 and in the next series from 0.51 to 1.47, there being nothing to indicate the behavior of the metal within the wide range of variation between 0.077 and 0.51.)

Among other things these tests have clearly demonstrated the danger of considering mechanical tests from the point of view of a few figures or a few properties only. As the phosphorus content is increased the metal becomes brittle, and the great decrease in ductility shows how unreliable are the ultimate tensile strength and the apparent elastic limit when considered alone. The tests have also shown the great differences resulting from the rate of cooling, and how useless it is to consider the results furnished by test prices that have been cast separately as indicating the quality of a casting. (Paper presented to the Nancy Congress of the Association Technique de Fonderie, abstracted through the *Foundry Trade Journal*, vol. 26, no. 323, Oct. 26, 1922, p. 344, *e*)

FORGING

Power-Plant Cost of Operating Hammers, R. E. Waldron. The variations in steam consumption for a given size of hammer depend entirely upon the condition of the hammer relative to its state of repair and valve adjustment. Another very important item is the condition of the cylinder and piston rings. The main valve may be set in such a way that the hammer will operate satisfactorily as a tool, but not economically from the point of view of steam consumption.

The author gives four curves to show steam consumption per hour for hammers from 1000 to 8000 lb., the data being taken from various tests. The results vary considerably depending upon the condition of the hammers, which makes it impossible to state what the actual consumption of any particular size of hammer is.

The author indicates a way for obtaining a basis for the comparison of steam costs for hammers.

One feature of importance has been brought out by analyzing the test results for the four hammers and, that is, that it is more expensive per 100 lb. of falling weight to operate small steam hammers than large ones.

Furthermore, steam consumption, or rather steam costs on a hammer, is greatly affected by conditions of operation, and is much less in shops working 24 hr. per day than in single-shift shops. (*Forging and Heat Treating*, vol. 8, no. 10, Oct., 1922, pp. 474–476, 7 figs., *t*)

FOUNDRY

Magnesium Castings, Carl Irresberger. A general discussion of magnesium and its alloys, together with practical data on casting articles from these metals and on the physical properties of magnesium castings.

Iron crucibles with gastight iron covers are recommended for melting magnesium and electron metal, these metals, unlike aluminum, having no tendency to attack iron. On the other hand, magnesium and its alloys even at comparatively low temperatures become plastic and from that point on manifest an increasing tendency to absorb gases of all kinds, which makes a reliable gastight cover on the crucible a basic condition of success in melting. Graphite crucibles should not be used, as magnesium absorbs from them considerable amounts of silicon.

Molds for magnesium castings may be made in sand, but satisfactory results have also beeen obtained with permanent iron molds. In order to avoid the danger of explosions, the molds should be thoroughly dried, say, at a temperature of 450 deg. cent. (842 deg. fahr.), at which temperature the chemically combined water in the clayey parts of the sand is driven out. Plenty of risers of generous proportions should be provided.

Extreme care should be taken not to leave any moisture in the mold. At high temperatures magnesium forms with water or water vapor white magnesium oxide and hydrogen, and the latter, together with air, forms a highly explosive mixture which is easily ignited by contact with the hot metal.

The article discusses magnesium foundry methods in considerable detail. It would appear that magnesium castings may show various colors on the outside, which depend apparently on the temperature of pouring and the degree of dryness of the mold. If the metal was poured at a correct, not excessively high, temperature in perfectly dry molds, the exterior skin of the casting should be of a silvery color. If poured at an excessively high temperature it will be of a bluish iridescent color, probably because of absorption of some silicon from the sand. If the temperature of pouring was right and the mold was not perfectly dry, a dirty grayish color will be shown, but in any event a brilliant silvery white may be imparted to the casting by pickling it in nitric acid of density 180 deg. Baumé, free from chlorine.

For castings magnesium is chiefly used in the form of electron metal which contains from 90 to 99 per cent of magnesium and from 10 to 1 per cent of a metal such as aluminum, zinc, magnesium or cadmium. They machine much better than aluminum and are used in particular where lightness of the part is a material consideration. Magnesium alloys have been used for perforated plates in textile machinery where the plate has to carry thousands of fine holes and where the slightest imperfection in the casting would make the product worthless. They proved to be perfectly satisfactory for this purpose. Magnesium alloys have been also used for spindles, one advantage being that owing to their lower weight as compared with iron they can be brought to speed in one third the time required for the latter. (*Giesserei Zeitung*, vol. 19, no. 41, Oct. 17, 1922, pp. 599–602, *p*)

GAS PRODUCERS

THE TREAT GAS PRODUCER. Description of a mechanical gas producer invented by F. H. Treat. The chief distinctive features of this producer consist in a number of devices and power-actuated mechanisms which perform automatically various functions in relation to the fuel bed. Thus, a mechanism is provided for agitating the fuel bed and for feeding and distributing the fuel in the producer chamber. The machine to do this is located in the central circular opening of the producer top and is arranged to revolve bodily at a slow rate in a horizontal direction. The action for feeding and distributing the fuel and the agitation of the fuel bed functions in unison with the rotary movement.

The machine has a number of agitator bars extending vertically within the producer chamber so that the pair of agitator fingers of the lower ends penetrate the fuel bed. By turning adjusting screws the agitator bars may be raised and lowered at the will of the attendant. Fuel-feeding devices are provided. The blast is supplied through eight independently controlled steam-jet blowers of special design which are disposed uniformly around the outside of the producer. To each blower is connected an independent tuyere pipe which is arranged to extend through the tapering lower portion of the producer body and into the ash zone. The ashes are discharged through a water seal over the edge of the ashpan and a scraper device is employed which is designed to act against the interior surface of the ashpan.

The original article describes the various mechanisms in detail and illustrates some of them. No data of tests or performances in practice are given. (*Iron Trade Review*, vol. 71, no. 20, Nov. 16, 1922, pp. 1351–1354, 3 figs., *d*)

MARINE ENGINEERING

Wind-Propeller Drive for Boats

DRIVING A BOAT AGAINST THE WIND BY AN AIR MOTOR. Description of the experiments of Constantin Joessel and Daloz on driving a 6-ton fishing vessel by wind force in any direction, i.e., with or against the wind. It is obvious that this could not be done by means of sails in which the pressure is always normal to the sail and a motor of the windmill type had to be used. In this motor, which is of the variable-propeller type, it is necessary on one hand to consider the pressure exerted by the wind on the system in motion, and on the other the energy of rotation obtained on the axis by the movement of the blades, this energy being transmissible to a suitable propeller. The water propeller like the air propeller gives an axial thrust which is a function of the energy of rotation that it receives. In order, therefore, to drive a boat it becomes necessary to create conditions under which the axial thrust of the water propeller will be greater than the component along the axis of the ship of the axial thrust due to the movement of the air propeller. If the axial thrust of the water screw be greater than the total axial thrust of the air propeller, the boat will be able to move against the wind.

Calculations and tests made on a small apparatus with fans as the source of the wind have shown that the problem was capable of solution provided the screws have suitable dimensions and are connected in such a manner as to produce a suitable speed ratio.

As a first step it was necessary to determine the number of blades in the air propeller that would give the best efficiency. Numerous tests have shown that the two-blade propeller is the best.

In the installation on the *LeBois-Rosé*, a fishing vessel of 6 tons capacity, the air propeller is 9 meters in diameter and the blades

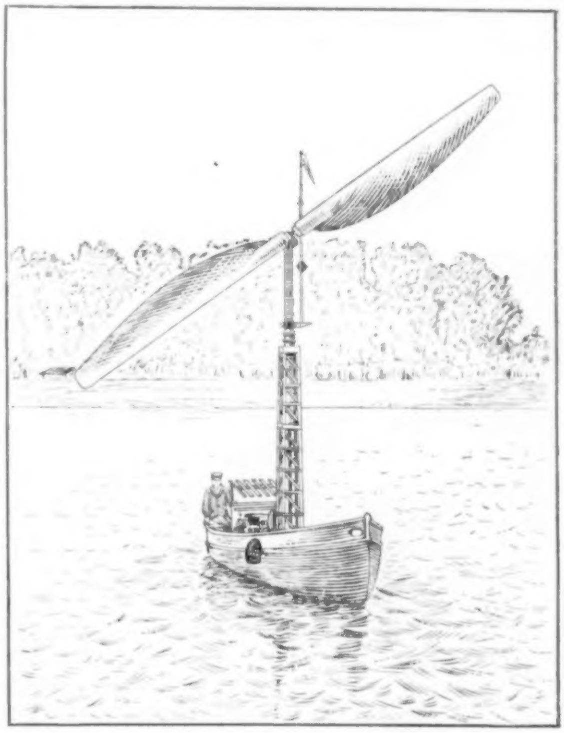


FIG. 2 AIR-SCREW-PROPELLED VESSEL CAPABLE OF BREASTING THE WIND

are made of laminated wood. The water propeller, is of the 4-blade type, made of bronze, and 1.05 meters in diameter. Both the air and water propellers are of variable pitch. In order to save expense in installation there is no speed-gear change between the air and water propeller, such as was used in preliminary tests. This lowers the efficiency of the boat, but it is still perfectly able to run into the wind or across it.

The shifting of the air propeller, which must always be in a position normal to the wind, is effected by means of a worm gear which the pilot can operate simultaneously with the steering gear. It would be possible, however, to make the air propeller take its position automatically. In the experimental vessel serious difficulties arose due to the fact that the weight of the superstructure proved to be quite great and that the reaction of the wind on the propeller located at the top of the tower serving as a mast gave rise to a couple of considerable magnitude. It is claimed, however, that with suitable devices provided to take care of this situation, the boat has proved to be highly maneuverable, and with one man on board has been able to navigate successfully a crowded part of the River Seine between Sèvres and Saint-Cloud. The general appearance of the boat may be judged from Fig. 2. No data of the actual speeds attained with the various wind velocities are given. (Paper before the French Academy of Sciences, read Oct. 23. Abstracted through *Le Génie Civil*, vol. 81, no. 19, Nov. 16, 1922, pp. 421–422, 1 fig., *dA*)

MACHINE DESIGN AND PARTS

Gear Noises and Their Causes—Apparatus for Detecting Errors in Gears

Some Causes of Gear-Tooth Errors and Their Detection, K. L. Herrmann. The author analyzes the different gear noises and their causes and comes to the conclusion that production variables have a much greater influence on gear sounds than the changing pressure angles used or tooth-form detail.

The first of the gear noises discussed by the writer is a knock that might be caused by a nicked tooth or a single tooth of a pair of running gears that are in mesh. The same result may be produced by inaccurate conditions in the gears. For example, should the tooth spacing in a transmission drive pinion be such that the driven gear instead of rotating at a uniform speed is forced to increase or decrease its speed at every revolution of the pinion, there will be a noise. To avoid this it is not sufficient to check gears for spacing error from tooth to tooth. It is very desirable to check the accumulated error of a number of teeth because a gear may vary 0.001 in. from tooth to tooth. With eight successive teeth each gaining 0.001 in. on the side of the gear and a similar number of teeth that may be loosing 0.001 in., a total error of 0.016 in. might be imparted to the driven gear.

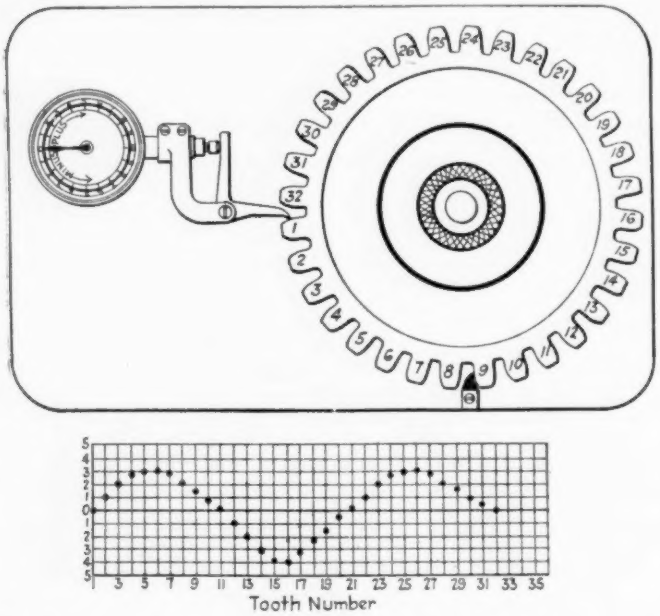


Fig. 3 Device Used for Checking Tooth Spacing and (Underneath) a Chart Showing the Results Obtained

Fig. 3 illustrates a very simple device that has been used for checking tooth spacing. The gears are mounted on a bushing and one tooth comes against a stop. A dial indicator is arranged so as to be in contact with some tooth one-fourth, one-third, or one-half way around the gear. When the dial indicator is set at zero, with the tooth against the top at any one point, the distances between the two points can be measured and, if the gear be correct for indexing, placing any of the two teeth in the gear in similar positions should not cause the dial indicator to vary, especially if the gear runs true.

When the gear is first put on the indicating apparatus, the dial indicator is set at zero. A mark is then put at zero on the chart in Fig. 3. for tooth No. 1. The next step is to index the gear around to one tooth. Any reading obtained is marked above the tooth in vertical line. The gear is next indexed around to tooth No. 3 and the dial indicator reading is marked opposite the number of thousandths of an inch that it may show. The gear is then indexed to teeth Nos. 5, 6, etc., until all the teeth on the gear have been indexed.

For the purpose of record, we now have a chart showing the accumulated variables. It will be seen from Fig. 3 that at no point is the spacing variable as great as 0.001 in. between any two teeth, but it can be in error a total of 0.008 in. or more when the error between the several teeth has accumulated. A better visual demonstration of this condition occurring in gears is made by means of a gear-tooth-form projector. When a gear-tooth form is projected upon a screen by this device, it will be noted that the magnification of the shadow is 100 to 1, and that for every inch on the screen there is at least a 0.001-in. error somewhere in the gear. The shadow on the screen also shows the variation in uniform movement of the driven gear due to an error of this kind; that is, the driven gear, instead of having its tooth in the position of the outline on the screen, has been forced to advance a number of thousandths of an inch. It will be noticed, further, that this advance and retardation does not occur uniformly; that is, the advance may be confined to a very small number of teeth, remain there for a certain length of time, and then be retarded slowly. A gear in this condition will give a rattle very similar to that which might be produced by unequal spacing. This condition can be studied best by charting it as described.

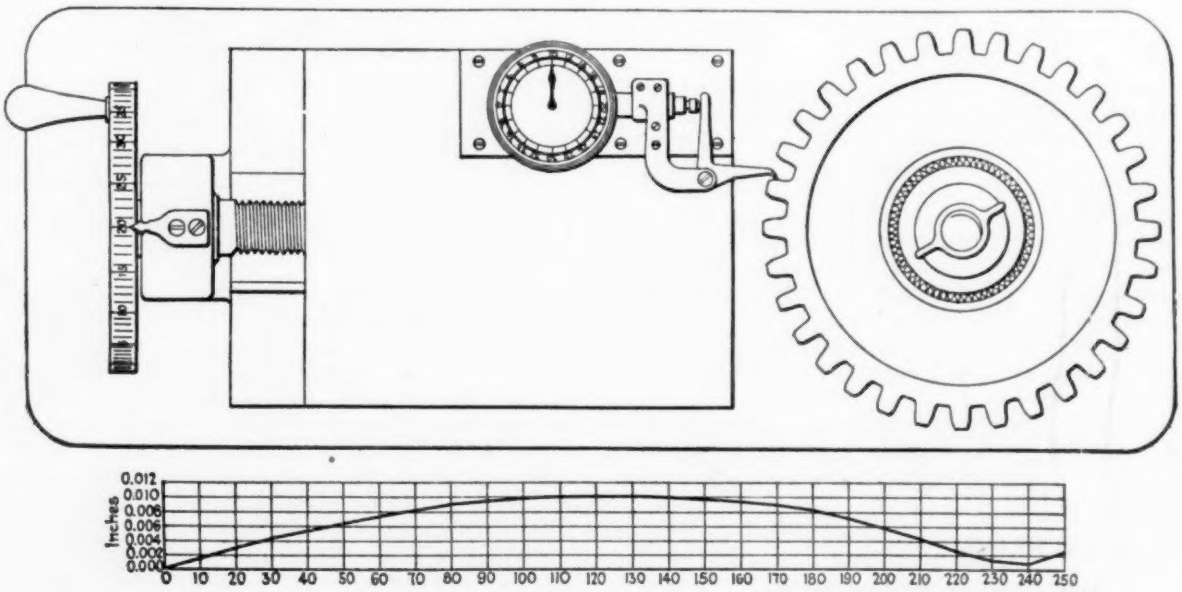


Fig. 4 Instrument for Obtaining an Analysis of Tooth-Forms Producing Noise and a Chart Showing the Outline of a Particular Tooth

In addition to the two gears having a rather irregular action between themselves, their increasing and decreasing movement is carried on to the countershaft and the idler which often have similar

defects in themselves. Accumulating errors in gears often cause the fourth gear in a train to be as much as 0.025 in. away from its correct position. The countershaft then does not rotate smoothly and the gear at the other end of the countershaft in addition to the variable movement given it by the errors in the first two gears imparts its error to the gear meshing with it.

Fig. 4 shows an instrument developed by the author for the purpose of analyzing tooth forms producing the various sounds. It consists of a dial indicator mounted on a guided slide. The gear is placed in a definite position with respect to the indicator, when the operator starts at the point of the tooth and sets the indicator at zero. The slide is then moved toward the gear 0.010 in. and the indicator reading marked on the chart shown in the lower portion of Fig. 4. The slide is then moved 0.010 in. more, the reading is marked again, and this is continued until the bottom of the tooth is reached. By taking the gear that has just been charted off the bushing and placing another gear in its place, other tooth forms will be compared with the first.

The causes of the errors in gears referred to are various, some of them occurring in hardening, some of the cutting machines, and some in the cutters. To show this the author discusses the case of the hobbing machine and its possibilities for error, and also gives charts showing the conditions of the gear before and after hardening. From this it would appear that at times the hardening errors compensate for the cutting errors, while at other times the hardening errors cumulatively add themselves to the cutting errors. (*Journal of the Society of Automotive Engineers*, vol. 11, no. 5, Nov., 1922, pp. 391–397, 14 figs., *eA*. Abstract in *Automotive Industries*, vol. 47, no. 18, Nov. 2, 1922, pp. 869–873, 14 figs.)

MACHINE DESIGN

Epicyclic Gears and Gear-Ratio Diagram

Epicyclic Gears: the Gear-Ratio Diagram, P. Cormack. A diagram intended to be used for computing speed ratios of an epicyclic gear set. It is said that this diagram gives complete generality to the solution of problems on wheel trains and shows the properties of trains when used epicyclically. The diagram may also be applied to rotational accelerations.

Fig. 5 Cormack Gear-Ratio Diagram

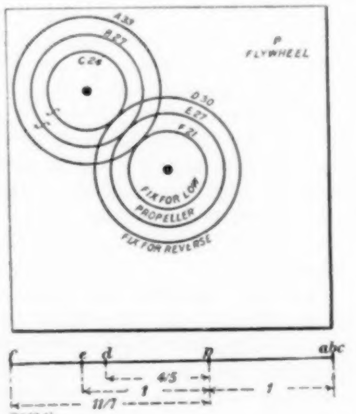


Fig. 6 Ford Epicyclic Gear and Gear-Ratio Diagram

Gear-Ratio Diagram. If the segments $p\,a$, $p\,b$, $p\,c$, $\ldots$, $p\,q$ of a line, Fig. 5, be proportional to the speeds of the wheels A, B, C, $\ldots$, Q, of a wheel train when P is fixed, then the segments $q\,a$, $q\,b$, $q\,c$, $\ldots$, $q\,p$, are proportional to the speeds of the wheels A, B, C, $\ldots$, P, when Q is fixed. A formal proof of this proposition may be obtained by considering the fixing of Q as being due to the imparting to the whole train of a motion equal and opposite to that possessed by Q. Thus, let a rotation $q\,p$ be added to the rotation $p\,a$, $p\,b$, $p\,c$, $\ldots$, $p\,q$, of $A, B, C, \ldots Q$, and P. The resultants are:

$$
\begin{aligned}
\text{Rotation of } A &= q\,p + p\,a = q\,a \\
\text{Rotation of } B &= p\,q + p\,b = q\,b \\
\text{Rotation of } C &= q\,p + p\,c = q\,c \\
\text{Rotation of } Q &= q\,p + p\,q = 0 \\
\text{Rotation of } P &= q\,p + 0 = q\,p
\end{aligned}
$$

Hence the proof.

Application to Epicyclic Gear Set. As an example the author shows how the gear ratios of the Ford motor-car transmission gear are exhibited by the diagram. This gear is shown in Fig. 6. The engine flywheel P carries the axle of the planet group $A\,B\,C$. B meshes with E, the propeller shaft; A meshes with F, which is fixed for the slow speed; and C meshes with D, which is fixed for the reverse. Taking P to be fixed, if A make one turn, so will B and C, since they are keyed to A. One turn of A gives $-33/21$ turns of F; one turn of B gives -1 turn of E; one turn of C gives $-24/30$ turns of D. To construct the gear-ratio diagram, therefore, draw $p\,a = p\,b = p\,c = 1$; $p\,f = -33/21$ or $-11/7$; $p\,e = -1$; $p\,d = -24/30$ or $-4/5$. We can now read off the low-gear ratio of the propeller E to the flywheel P, when F is fixed. It is $f\,e/f\,p$. Since $f\,e = 11/7 - 1 = 4/7$, and $f\,p = 11/7$, the low-gear ratio $f\,e/f\,p$ becomes $4/11$.

With D fixed, as it is for the reverse gear, we have the speeds of the flywheel P and the propeller shaft E proportional to $d\,p$ and $d\,e$. The lines $d\,e$ and $d\,p$ being in opposite directions show that E and P revolve in opposite senses. Numerically $d\,e = 1 - 4/5$ or $1/5$, while $d\,p = 4/5$. The reverse gear ratio $d\,e/d\,p$ is therefore $1/4$.

Angular Acceleration. Corresponding to the proposition of the second paragraph of this abstract for rotational velocities, we have the analogous proposition for rotational accelerations, a statement and proof of which is given in the second paragraph, if "angular acceleration" be written for the words "speed," "rotation," and "motion" occurring therein. (*Engineering*, vol. 114, no. 2965, Oct. 27, 1922, p. 511, *tp*)

MACHINE SHOP (See also Machine Design and Parts; Measuring and Testing)

Processing Spline Shafts by a New Method, James A. Ford. In this method a die is constructed according to the same principles that apply to the automatic threading dies now in general usage, the cutters being in the position that the die chasers ordinarily would occupy. The cam ring is practically of the same construction as that used on a threading die, except that the ring is made stronger. This opening feature is necessary on account of having to pass the shaft back through the die, because the body of the shaft beyond the splines is larger than the body portion between the splines, and the shaft will not pass completely through the die.

The shaft is entered into a bushing that is lined up with the die. Then the shaft is pressed through the die to a stop that has been set at a sufficient distance to permit the shaft to pass through to the shaft neck at the end of the splines. The cutters in the die are then released and the shaft is removed.

During the experiments with this die it was ascertained that a clearance angle on the cutter of 30 min. was about correct, and it was decided that one pass of the shaft through the die gave the most satisfactory result.

It is stated also that a method has been found to straighten the shafts to within 0.005 in. per ft. of being out of parallel with the true axis of the shaft. It is not stated how this was done. (*Journal of the Society of Automotive Engineers*, vol. 11, no. 5, Nov., 1922, pp. 433–434, 4 figs., *d*)

Manufacturing Distance Pieces. Description of machining processes and equipment. The piece is produced in four operations. First, the tube is cut to length in a press, next both ends are surface-ground in a surface grinder, then the hole is pierced in a press, and lastly the bore is ground in an internal grinder.

As to the first operation, namely, cutting the tube to length, the difficulty of preventing distortion under the shearing action must be overcome. This was accomplished by a device described in the original article in which the tubular stock is sheared.

The grinding of the ends of the tube, which is the second operation, is carried out in a surface grinder on a magnetic chuck. For the third operation a simple semi-automatic fixture described and illustrated in the original article is used.

Grinding the bore is the final operation, and in view of the fact that the internal dimensions are held to close limits, grinding is essential as it rectifies a slight distortion which may have taken place during the punching of the hole, and in addition removes burrs. This operation must be carried out carefully, as precaution must be taken to avoid the use of clamping devices that would cause distortion. For this purpose a special fixture has been designed, which is described and illustrated in the original article. (In this connection it may be noted that the fixture for internal

grinding is referred to as Fig. 4 in the text of the original article. It is really Fig. 3.) (*Engineering Production*, vol. 5, no. 109, Nov. 2, 1922, pp. 411–413, 3 figs., *d*)

MEASURING AND TESTING

Sound-Testing Devices—Testing Machinery by Sound

Detection, Location and Comparison of Sound, C. E. Noël-Storr. For a long time there has been an effort to build testing devices that would make it possible to determine and, in particular, locate irregularities in operation of machinery by the sound emitted.

The author developed his initial apparatus in order to locate mechanical defects in a series of very large engines which did not run quite right. To do this he devised an instrument with two ear pieces and flexible connections to the reproducer. While the device was crude and far from efficient, the difficulty in the engines was traced with very little trouble and with perfect comfort. Later on another problem arose in connection with small gear boxes which contained a double-reduction spur gear mounted on ball bearings. Some of these boxes failed to pass inspection on the ground of excessive noise. A difficulty also arose on account of the irregularity of the rejections, since batches considered noisy by the test room would perfectly pass, while nominally silent batches failed to do so, due, of course, to the entire lack of any definite standard of reference for either the inspector or the works staff. It therefore became desirable to find a way of measuring the sound of the boxes.

The construction of instruments for the detection and location of sound is complicated by the fact that in connection with mechanical work there are two distinct purposes for which such instruments may be applied, namely, the detection of internal or mechanical sound and external or atmospheric sound. For example, in examination of the running condition of the balls in a journal bearing the internal sound only is of interest and not any external noise the bearing may make. On the other hand, in many forms of construction it is desired to reduce the external noise to a minimum and it is quite possible that a test of the internal sound may lead in such cases to a totally incorrect conclusion.

To deal with the two different aspects of the matter there are two different types of reproducer. In the first place, there is the tectoscope, which is arranged with a test rod and reproduces only the internal sound of the bar with which the rod is in contact. The tectophone, on the other hand, is arranged with a conical mouth and reproduces the external sound when the mouthpiece is held close to any object.

It will be noted at once that one instrument serves to check the results obtained with the other. For example, the contact breaker of a magneto will show a considerable blow from the rocker arm when tested with the tectoscope, but except on a few very silent engines the blow will not be heard externally when tested with the tectophone. In other words, the first instrument will indicate that there is a distinct mechanical blow taking place, and the second test will show that in the matter of improving the general silence of operation this blow is of small moment.

The foregoing example serves to show that the clear reproduction of even minute internal noises should enable worn or faulty parts to be located quite easily, while it also brings forward the use of the second type of instrument for checking the amount of external noise arising from a given internal source. Thus parts which may give rise to external noises may be traced, although it is more than likely that in some cases the internal cause is of small magnitude.

There are other general applications of the tectophone; for example, there may be two universal joints on a common shaft, and either or both may be dry and noisy. In some cases of this nature the tectoscope applied to the nearest bearing on the shaft might fail to give a clear indication on account of the noise of the bearing, but if the tectophone is held quite close to each joint in turn the squeak can be instantly located. The above instance applies to many similar problems and includes the tracing of gas, compressed air, and similar leaks from pipes and plant in general, the flow of a liquid in the pipe being indicated quite distinctly by the tectoscope.

The author gives descriptions of ways to proceed in testing the operation of various parts of an automobile engine, selected here as an example, by means of his apparatus. Sounds picked up by this apparatus may be compared either with each other or with a standard which is to be taken as a fixed quantity. For general shop tests a pair of reproducers are used connected to the head frame. If, for example, the left-hand reproducer is placed in contact with No. 1 cylinder, the sound emanating therefrom will be the only sound audible to the operator. On placing the right-hand reproducer in contact with No. 3, however, the relative "slap" of the two cylinders can be instantly compared, this being preferable to an attempt to remember the relative intensity of No. 1 and making a mental comparison after testing No. 3.

It should also be noted that when required the method enables the internal sound to be compared with the external; and as in some forms of construction the section or shape of the casing may cause, say, four tappets and cams which are all of equal intensity internally to give very different external effects, the combined test should enable any confusion to be avoided as to the actual cause of the defect. In fact, it should be of considerable assistance in the industry for purposes as widely different as the choice of suitable material for the exhaust pipe and the design of a gear-box lid.

Other applications of the use of this apparatus are described, from which it would appear that by these means a considerable amount of information can be obtained at a small expense in time. For example, many sources of trouble in closed bodies can be easily obviated with the aid of the tectophone which will trace body squeaks, panel drumming, and the periodic drumming of wings and undershields under actual running conditions on the road. (Paper presented to the Coventry Branch of the Institution of Production Engineers, Nov. 7, 1922, abstracted through *Engineering Production*, vol. 5, no. 110, Nov. 9, 1922, pp. 439–443, 9 figs., *dA*)

MECHANICS (See Machine Design and Parts)

POWER-PLANT ENGINEERING (See also Forging)

Power-Station Design

Power-Station Design, C. W. E. Clarke, Mem. Am.Soc.M.E. Apart from market conditions for the sale of electrical energy, the author considers as the controlling factor in the selection of a power-station site the existence of an adequate supply of water for condensing purposes at all times, and from this point of view thinks that the so-called "mine-mouth" power plants would be of advantage in only very few locations.

The paper discusses the various features of design in considerable detail. Only a few points, however, can be reported here. The use of double stokers, that is, two stokers placed face to face, is seldom of advantage and the author considers it as justified only in cases where the boiler heating surface per square foot of floor area is very great, or when it is expected to operate boilers at very high ratings.

The use of pulverized fuel has only just passed the experimental stage, but there is little doubt that this system will be used in many of the plants built in the future, especially where only low-grade fuels are available. It has many advantages in efficiency and operating simplicity, but the additional cost of the system may militate against its wider adoption. Oil is the ideal fuel for use under boilers, but with the present relative costs of coal and oil it cannot be used economically for power-station work except in certain localities.

The installation of economizers, with fuel costs at their present level, is of doubtful advantage.

When increased building, economizer, induced-draft, fan, piping, maintenance, and operating costs are considered it will usually be found that an increase in the height of the boiler will result in a greater operating efficiency, considered financially, than if economizers are used. The curve in Fig. 7 shows a comparison between the efficiencies of a 15-high boiler with 64 per cent economizer and a 20-high boiler with no economizer. Every case should be considered in the light of its own peculiar conditions, but this curve is illustrative of the general trend.

Surface condensers are usually to be preferred to jet condensers because the pure condensate is available for boiler-feed purposes,

making elaborate systems for water treatment unnecessary. If there is a supply of good boiler feedwater available, which is rarely the case, a jet condenser is about as economical financially as a surface condenser. All surface condensers should be provided with some sort of screen to remove leaves and other matter from the condensing water. For this purpose a traveling screen is the only suitable apparatus. The water velocity through the free opening of screens should not exceed 2 ft. per sec., unless such a velocity requires extraordinarily large screens.

The only method left for improving the overall efficiency of a power station is through the system of heat conservation which goes under the general title of the "heat-balance system." Boiler design has reached a point beyond which little can be expected. Turbine generating equipment gives us efficiencies about as high as we can look for. We are then faced with the proposition of making the system of heat utilization in the station as efficient as possible. At best, there is only a little over 30 per cent of the energy put into the steam by the boiler which is available for conversion into power. The problem is how to approach as closely as possible to converting all this energy into power. This can be accomplished only by retaining in the station heat cycle as much as possible of the latent heat

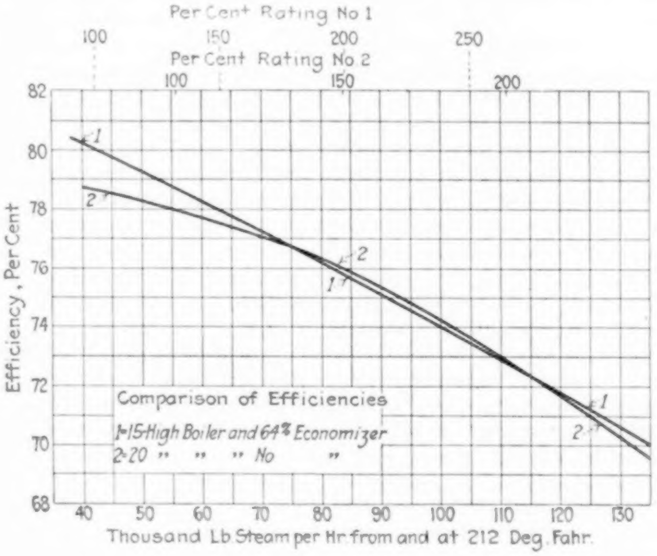


Fig. 7 Comparison of Boiler and Boiler-Economizer Unit

of the steam which ordinarily is transferred to the condensing water. A heat-balance system has this object in view.

There are four general methods of heat balance and the author discusses them in detail. For large stations he considers the following as the best system: House turbine, alternating current or direct current and electric drive for all but enough of the auxiliaries to keep the station running in case of accident to the house turbine and main generator.

Among other things, the article contains an interesting table giving piping and fitting schedules, as well as pipe materials best adapted for use in power-station work. (*Proceedings of the Engineers' Society of Western Pennsylvania*, vol. 38, no. 4, May, 1922, pp. 109–127, 1 fig. and 1 table, and discussion, pp. 128–167, 10 figs., *g*)

Slag on Boiler Tubes

Formation of Slag on Boiler Tubes, Harry H. Bates. The author claims that slag formation on boiler tubes and walls is essentially governed by the same rules as apply to clinker formation, and points out that in slag the iron must be kept in the ferric state, which is practically infusible. This can only be done by completely oxidizing the sulphur and iron before the tubes are reached.

All types of stokers have difficulty with slag formation and it is believed that slag particles are carried up with the draft in such minute form that they can be transported by the low-velocity gas as well as by the gas that rises rapidly.

An examination of the slag under the microscope revealed small spherical globules, substantiating the belief that the particularly troublesome particles were the small ones.

When these small particles come in contact with the free oxygen in the furnace gas for a sufficient time to oxidize them completely, they will be transformed into their completely oxidized state and become solid. If they solidify before touching the tubes or walls, they are carried through the boiler as solid ash. On the other hand, no free oxygen is obtained through the fuel bed. In this event the particles remain in a molten condition, on account of their low fusing temperature in their their -ous state, and are deposited on the tubes and walls where they may either be completely oxidized and solidified or be covered by successive coatings or layers of the same plastic material.

That the latter is true to a large extent is shown by layers of a very dark vitreous material covered by a reddish brown layer or protective coating. This reddish coating is largely ferric material and it prevents further oxidation of the dark ferrous material within by excluding the oxygen from it. A considerable portion of the material on the outer surface, especially on the tubes, is of a friable and nonfusible character, and it is of a completely oxidized nature.

The author calls attention to various efforts made for producing complete combustion in large furnaces, but points out that even if some efficient means is developed for mixing the gas and excess air together, it is very questionable whether the slag difficulty will be entirely overcome. It is to be remembered that in addition to the problem of supplying and mixing the oxygen and combustible gases, time is required for the various chemical reactions to take place.

There is but little chance for thoroughly mixing all gases in the combustion chamber, as the rapid rate with which the gases ascend prevents a thorough mixing, so that stratification of the gases results.

In proof of the above the author gives analyses of samples taken from the first-pass baffle opening of a boiler immediately under the first row of tubes.

These readings showed a carbon dioxide content of from 10.0 per cent along the walls to 17.5 per cent in the center. From these figures it can be appreciated that the chances for the ferrous material to change into the ferric state are very few. It was evident that there was an insufficient penetrative effect from the ventilated walls to take care of the wide furnace, and it is also noted that there was considerable excess air along the walls.

Numerous samples of coal ash and slag were analyzed and it was found that the slag on the furnace walls ran much higher in ferrous iron, by per cent, than did the slag on the tubes. In consequence of this the slag on the walls was much freer from the coarse, friable, infusible material than was the material on the tubes.

Numerous theories were advanced during this investigation as to the causes of slag formation on the tubes. Chief among these was the condensation of tarry vapors on the tubes, to which the flying particles could adhere and solidify.

Whether condensation of tar can actually occur is, however, subject to doubt in view of the facts pointed out by the author.

In the large number of tests made it was indicated that the slag deposit on the tubes was nearly proportional to the total amount of gas, and was not greatly affected by the rating. The amount of slag was affected by the temperatures in the furnace, however, for the hotter fires kept the slag in a more viscous state, which greatly increased the tendency for cinders and particles of ash to adhere.

In trying to prevent slag accumulation three methods were considered. Among these the injection of steam into the air supply was tried, but no decrease was noticed in the formation of slag on the tubes. Another method now being tried is that of intimately mixing air with the gases. The original boilers were set about 13 ft. from the grates. It was thought that by increasing the distance between the grates and boiler tubes the gases would have more opportunity to mix thoroughly. Also, since the total time of travel of the furnace gas is dependent upon the velocity and distance of gas travel, more time would be allowed for complete oxidation of the small particles. Consequently a boiler was set up 6 ft. higher than those originally installed.

Assuming that the rapidity with which the gas rises from the fuel bed is uniform, it is calculated that its velocity was about 18 ft. per sec. This is the lowest possible velocity that can be expected. The direction of gas travel is from the grate direct to the baffle opening, which was proportioned as 46 per cent of the grate surface.

Necessarily the velocity was twice as high under the baffle as it was leaving the fuel bed.

On this basis the time it took for particles to reach the tubes with the original installation would be 0.72 sec. This is very little time for oxidization to take place, unless it is of an explosive character. Further, by raising the boiler to 19 ft. this same time would be 1.05 sec., which is still a very short period.

This arrangement has not shown any great improvement in slag prevention and has the disadvantage of exposing more brickwork to high temperatures and to draft, with resulting greater infiltration of air through the setting.

Furnace construction undoubtedly has much to do with the external incrustation of the tubes with slag. The ratio of the exposed tube surface to the grate area was 1 to 1. This is very low and the lower the ratio, under set conditions of fuel and fuel bed, the higher will be the furnace temperature. It is apparent that the higher the furnace temperature, the greater will be the tendency for the ash to fuse and stick.

It has become common practice now to have the ratio of exposed tube surface to grate surface as high as 1.87 to 1, and it is seldom less than 1.2 to 1. By increasing this ratio the amount of heat radiated up and absorbed is very materially increased, with a consequent reduction in furnace temperature. This last item, namely, furnace construction, is a step in the right direction.

It is extremely fortunate that only a comparatively few coals give slag trouble to a serious degree. A great many coals have fusing temperatures so high that they give no trouble with ordinary furnace temperatures. Another class of coals have low fusing temperatures, but do not seem to have the tendency to be lifted from the fuel bed. But when a coal gives serious slag trouble, with the present knowledge of the art of burning coal, means must be provided for its mechanical removal. This, however, is not as serious a matter as it appears, for soot blowing in boiler plants is now recognized as a necessity, and apparatus for soot removal is now installed as regular boiler equipment. (*Power Plant Engineering*, vol. 26, no. 22, Nov. 15, 1922, pp. 1094–1098, 7 figs., *eA*)

Electric Steam Generators

ELECTRIC STEAM GENERATOR, E. M. Horstkotte. Description of an electric steam generator designed by the General Electric Co. It is stated that it requires power at the approximate rate of 1 kw-hr. for every 3 lb. of steam generated. The complete equipment consists of the shell with supporting feet, the electrodes, insulators, steam and water gages, safety valve, circulating pump and motor, and a panel on which is mounted the control equipment. The electrodes are of round iron and the electrical operation resembles somewhat that of a three-phase arc furnace.

Normally, the electrodes are submerged in the water, and the three-phase current passes through the water to the sides of the tank and to the neutral of the system, also from electrode to electrode. The steam is generated by current flowing through the water, which is of high resistance. The mechanical circulation of the water has been described, but some of the operating features arising from it are of sufficient interest to merit further consideration. One result is that the temperature of all the water in the system is practically uniform. If the steam pressure lowers owing to an increased demand, rapid steam generation, due to the high temperature of the water and the degree to which the electrodes are submerged, quickly brings the pressure up again.

Another operating feature is that since the water level is maintained by the adjustment of the throttle of the circulating pump, the energy consumption of the generator is not dependent on the operation of the feedwater pump. The supply of water in the hotwell is regulated by an automatic feedwater regulator. Furthermore, when it is desired to reduce the load, the generator does not have to be blown. The only energy losses in the circulating pump operation are the motor losses and the bearing-friction losses. Practically all the energy delivered to the pump impeller goes into heat in the water, therefore the loss from this source is small.

These electric steam generators have been designed for pressures ranging from 200 lb., maximum to 15 lb. minimum. Tentative layouts have also been made on generators of 3000 kw. capacity operating at 1 lb. pressure. These generators can be designed for any boiler pressure now being used, up to 50,000 kw. capacity and down to 250 to 300 kw. Below this lower limit generators of this type would probably not be as economical to build as some sort of immersion type using a metallic resistor.

One of the interesting features of operation of the electric steam generator is the interlocking of the various controls for purposes of safety. Suppose, for example, the circulating pump ceases to function, from voltage failure or other cause. The water in the electrode chamber simply drains into the hotwell, and since the electrodes are no longer submerged, no more steam is generated. On resumption of the pumping, since there is no hot metal surface in the electrode chamber, there is no danger of an explosion similar to that due to a hot crown sheet in a boiler. Also, when the water drains out there is no danger of burning any part of the electrode chamber, because when there is no water there is no heat generated. Too high a level of the water is prevented by an emergency overflow pipe of large diameter, whose top is some distance from the top of the electrode chamber.

There are instances where the electric steam generator might prove a valuable adjunct to the plant equipment either in utilizing excess electric power formerly wasted or in providing process steam directly where it is needed. An electric generator operates with only very little attention and therefore may be economically used under certain circumstances in preference to a steam generator.

This applies, in particular, to mills that purchase power on a maximum-demand basis. Suppose, for example, a factory contracts for 10,000 kw. maximum demand. It is possible that, owing to one cause or another, the load factor for the year may be as low as 75 per cent. In such a case 2500 kw-years, or 21,900,000 kw-hr., are being paid for but not used. By installing an electric steam generator to utilize this energy the fuel bills would be cut materially. Assuming a coal-fired boiler with an efficiency of 65 per cent and coal with 13,000 B.t.u. per lb., for every 4953 kw-hr. used in the generator one ton of coal would be saved, or 4421 tons per year. If oil-fired boilers are used, operating at 75 per cent efficiency and using oil weighing 8 lb. per gal. with 18,700 B.t.u. per lb., for every 32.9 kw-hr. there would be saved one gallon of oil, or 665,650 gal. per year. These figures are calculated on the basis that all the excess energy would be utilized. If only 75 per cent was so utilized, the savings is said to be still enough to more than justify the installation of a steam generator. (*Power*, vol. 56, no. 21, Nov. 21, 1922, pp. 795–797, 3 figs., *dA*)

In commenting on the progress of the electric boiler, an editorial in *Power* calls attention to the fact that there is installed or under construction in this country and in Canada about 200,000 kw. normal capacity of this kind of equipment. This is equivalent to the evaporation of 700,000 lb. of water per hr. from and at 212 deg. fahr.

While the size of this equipment varies, the average unit is large, and for 19 installations the average size of boiler is over 9000 kw. while the largest unit with a normal rating of 25,000 kw. has absorbed as high as 33,000 kw. (*Power*, vol. 56, no. 21, Nov. 21, 1922, pp. 811–812, editorial)

THE FLASH EVAPORATOR. Description of an apparatus for producing distilled make-up water made by the Schutte-Koerting Co.

The particular feature of this type of evaporator is that evaporation takes place in a chamber containing no tubes. This is accomplished by circulating the raw water continuously through the closed heater operated by exhaust steam to a vacuum flash chamber or evaporator and then back to the heater. In this apparatus the vapor discharge line of the flash chamber may be connected to the main unit condenser or to a special "distiller condenser." In this way a vacuum is maintained such that the temperature of the raw water leaving the closed heater is considerably above that corresponding to the absolute pressure in the flash chamber. The result is that as the water enters the chamber a certain fraction of it flashes into vapor. This passes over to the condenser and enters the system as distilled make-up water.

The following advantages are claimed for the flash evaporator; Elimination of evaporator scale trouble; removal of air and other gases; automatic control of evaporator feed and evaporator blow-down; and high rate of heat transmission in the heater due to the absence of a steam film between the tubes and the surrounding water. (*Power*, vol. 56, no. 22, Nov. 28, 1922, pp. 834–835, 3 figs., *d*)

POWER TRANSMISSION

Wave Transmission of Power

WAVE TRANSMISSION OF POWER. Description of the machinery and exposition of principles underlying the operation of the Constantinesco system of power transmission by waves generated in a liquid.

During the war this system was applied with great success in the so-called CC synchronizing gear for firing machine guns through aircraft propellers in such a manner as to avoid hitting the blades of the propeller. The apparatus proved to be so reliable that it was ultimately used for testing ammunition, it having been found that premature explosion and especially delayed ignition of ammunition powder was more liable to occur than irregularities in the operation of the gear. The patents in Great Britain and the Dominions are controlled by W. H. Dorman & Co., Ltd., who, among other things, have applied this method to the operation of hammer rock drills.

Notwithstanding the fact that until recently information available as to this process has been scarce and difficult to obtain, fairly complete particulars concerning it were given in MECHANICAL ENGINEERING, vol. 42, June and November, 1920, pp. 359–360 and 633–634.

The present article, among other things, gives data on the operation of the Dorman wave-power-driven rock drill as compared with a compressed-air drill.

Different figures have been published setting forth the performance of the Dorman wave-power rock drill. They show some considerable variation, as might be expected, in view of the fact that the rate of drilling must naturally depend upon the precise degree of hardness of the rock and upon the exact condition of the drill steel as regards sharpness. The first-named factor is not constant from hole to hole even on the one piece of rock, while the latter is subject to progressive deterioriation during the drilling of a hole to an extent which reflects the hardness of the rock. We give below a set of comparative figures which we ourselves observed in the course of a test made in our presence. The exact rate of drilling depends, of course, upon the operator to a considerable extent. He has it, at least, within his power, if skilful, completely to upset the value of the figures obtained in a comparative test. On the other hand, a close observer can readily tell when the operator is not working the drill to its full capacity, for if he holds it back at any time he must make it good afterward by turning the feed handle for a time at above the average rate. During the tests to which the following figures relate one operator—an employee of Messrs. Dorman—was employed throughout. We saw no evidence of any undue reduction in the feed during the compressed air drill trial. On the contrary, we noticed that with both drills occasional jamming occurred as a result of the steel being fed into the rock at slightly too great a rate.

TEST RESULTS ON HARD GRAY CORNISH GRANITE

Drill	Diameter of steel, in.		Feed per min., in.	Volts	Amperes
Wave transmission...	$1^7/_8$		$7^1/_2$	410	37.5
Wave transmission...		light load		410	22.5
Compressed air......	$1^7/_8$		$4^1/_2$	410	48.5
Compressed air......		light load		410	18.0

On the basis of these figures it will be seen that the Dorman drill performed about 75 per cent more work in the same time than the compressed-air drill, and consumed in so doing about 25 per cent less power. When running with the drill out of action, the Dorman drill consumed 25 per cent more power. The figures for the Dorman drill include the energy required to supply the flushing water. In the case of the compressed-air plant the flushing water was supplied by a separate pump, the energy consumption of which was not measured. The compressed-air drill was of a modern type—we cannot obviously specify its design—and was supplied by an air compressor of equally modern form. The compressor was not unduly large. In fact, it was only just large enough to drive the drill, as was shown by the fact that the receiver pressure fell slightly—from 82 lb. to 75 lb. per sq. in.—when the drill was brought into full action. It will be understood that the electrical consumption figures represent the energy supplied to the motors driving the wave-power generator and the air compressor, respectively. The same instruments were used in both cases. (*The Engineer*, vol. 134, nos. 3487 and 3488, Oct. 27 and Nov. 3, 1922, pp. 444–445 and 466–468, 8 figs., *deA*)

In view of the novelty of the subject and comparative difficulty of securing the necessary information, the following list of U. S. patents and patent applications on wave transmission held by the British W. H. Dorman & Co., Ltd., may be of interest:

PATENTS

1,211,679/17	1,334,287/20	1,334,281/20	1,334,282/20
14,738/19	1,334,280/20	1,334,290/20	1,372,944/21
1,334,283/20	1,334,288/20	1,334,291/20	1,334,285/20
1,334,284/20	1,334,289/20	1,372,941/21	1,372,942/21
1,372,943/21	1,410,100/22	1,400,019/21	

APPLICATIONS

495,221/21	495,222/21	415,861/20	415,119/20

This list is taken from a pamphlet printed for Mr. Walter Hadden, connected with W. H. Dorman & Co., in London, which gives, in addition to U. S. patents, patents issued in other countries including Great Britain.

PUMPS

Rotary Pump with Reduced Friction Losses

A NEW TYPE OF ROTARY PUMP WITH BLADES, A. Poitrineau. The general belief is that rotary pumps with blades are inefficient because of the excessive friction between the blade and the casing, rapid wear of parts, and excessive leakage.

The author considers (without, for the time being, going into the question as to how it can be done) the case of a rotary pump with blades where the blades do not come in actual contact with the

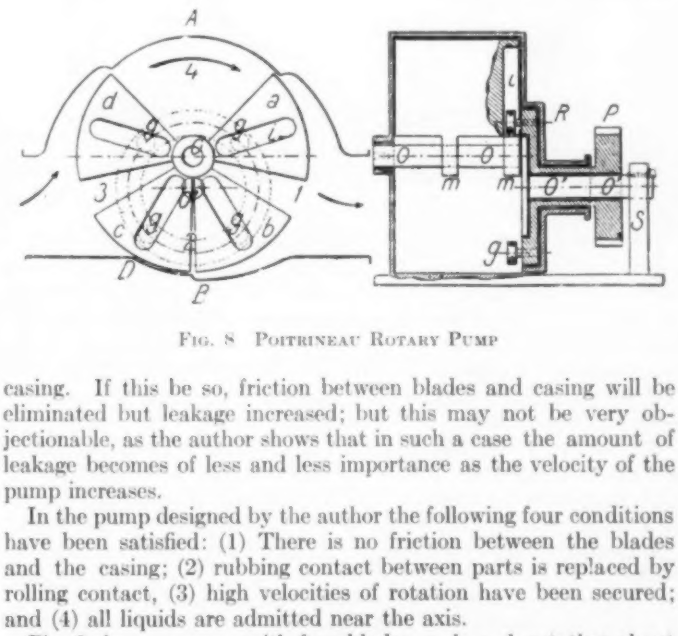


FIG. 8 POITRINEAU ROTARY PUMP

casing. If this be so, friction between blades and casing will be eliminated but leakage increased; but this may not be very objectionable, as the author shows that in such a case the amount of leakage becomes of less and less importance as the velocity of the pump increases.

In the pump designed by the author the following four conditions have been satisfied: (1) There is no friction between the blades and the casing; (2) rubbing contact between parts is replaced by rolling contact, (3) high velocities of rotation have been secured; and (4) all liquids are admitted near the axis.

Fig. 8 shows a pump with four blades, a, b, c, d, rotating about an axis O in a cylindrical casing with one orifice for water admission and another for its exit. A wheel R, driven by pulley P, revolves around the shaft $O'O'$. This wheel carries four equidistant rollers g which travel within rectilinear guides in the blades (i in the section). The operation of this pump is similar to other blade pumps with an eccentric drum—with this essential difference, however, that the drum is here replaced by the roller-bearing wheel R. The wheel R in rotating at a constant velocity carries with it the rollers which roll in their respective races and push the blades at velocities varying with their distance from the axis. In other words, it is simply a quick-return mechanism of the first order but of multiplex type. The thickness of the blades is so proportioned that at an instant when the bisecting planes form with the faces of two consecutive blades a minimum angle, the two adjacent walls are in touch. An examination of Fig. 8 shows that the two blades b and c, now in contact, will separate during one-half of the revolution and then tend to come together again. This will easily explain the method of taking in and driving out the liquid. In the case of Fig. 8, at each revolution a volume of liquid is delivered equal to four

times the volume 4, or practically equal to the volume within the casing.

The author explains the balancing of the parts at high speeds and the method of making the blade. From the article it is not clear whether any such pumps have been actually built, and if so, in what sizes and what were the actual efficiencies of the apparatus. (*Arts et Métiers*, vol. 75, no. 24, Sept., 1922, pp. 260–264, 9 figs., *d*)

RAILROAD ENGINEERING

Rowan Locomotive Piston Packing

ROWAN LOCOMOTIVE PISTON PACKING. Description of a type of locomotive piston packing applied on several of the Irish railways. The piston ring as applied to locomotive pistons is shown in Fig. 9.

There are two casting rings *A,A* turned to the exact diameter

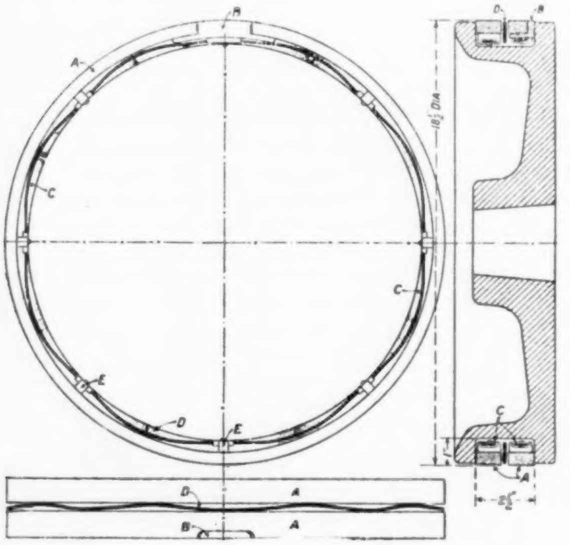


FIG. 9 ROWAN LOCOMOTIVE PISTON PACKING RINGS

of the cylinder, the split being covered by a steel spring *C* which consists of a hoop of steel of a diameter somewhat larger than the internal diameter of the ring. At intervals on the spring *C* there are a number of knuckles *E*. By forcing the hoop into the ring it is deflected from its circular form into a series of arcs—one between each pair of knuckles.

As shown by this the distinctive feature of this packing lies in the use of a separate spring to produce the proper expansion of each ring, with the addition of a third spring to keep the rings in steamtight contact with the outer side of the groove in the piston.

It is claimed that with this design each spring can be accurately adjusted for its particular function and that the pressure exerted by the rings against the cylinder walls does not exceed 2 lb. per sq. in. and is ordinarily about $1^1/_2$ lb. per sq. in., this being sufficient to insure steamtightness without causing excessive friction.

With superheated steam the piston springs are exposed to temperatures which draw the temper of ordinary spring steel. To meet this condition the manufacturers of the Rowan piston ring have developed an alloy having special heat-resisting and temper-retaining qualities which is being used in the manufacture of this locomotive piston packing. (*Railway Review*, vol. 71, no. 19, Nov. 4, 1922, pp. 615–616, 1 fig., *d*)

THE STREET LOCOMOTIVE STARTER. Description of a device the purpose of which is to give increased power to a locomotive at starting. Its function is different from that of the booster, as it is intended to assist the locomotive only when starting and is designed for use only at very low speeds. The starter consists essentially of a heavy cast-steel ratchet wheel driven by a steam cylinder. The piston of this cylinder is driven through its working or forward movement by steam pressure and through its return or backward movement by a spring. With the ratchet wheel goes a ratchet which can engage it and is carried by a pair of lever arms operated by the piston rod. When the machine is idle and during the return stroke of the piston this ratchet is held out of contact with the ratchet wheel. When steam pressure is admitted to the cylinder the ratchet is forced down into contact with the ratchet wheel and holds it there as long as the pressure exerted by the steam is greater than that of the springs which hold the ratchet up. The steam pressure and the strength of the springs are so proportioned that the ratchet is forced down before there is any forward movement of the main piston and lifted before its return movement. This arrangement eliminates any dragging of the ratchet over the ratchet wheel and the unnecessary wear and noise which would result if this were permitted.

The control mechanism consists of a 1-in. steam line leading from the dome of the locomotive to the cylinder of the starter with a throttle at the dome and a flexible joint at the cylinder. The throttle is opened and closed through the medium of a $^1/_4$-in. copper pipe leading from the throttle to a push button in the cap. When the push button is held down the machine will run, and when it is released it will stop.

It is important that all piping and the cylinders be free of water in order that the machine may respond instantly when action is demanded. To insure this the starter has an automatic drain valve at the lowest point of the cylinder which remains open at all times when there is a pressure of less than 10 lb. in the cylinder, and closes automatically under any greater pressure.

In the original article is shown a machine designed for application to a locomotive trailing truck having wheels 43 in. in diameter and carrying a weight of 52,500 lb.; the tractive force exerted at the rim of the wheel with a $10^1/_2$-in. cylinder and 200 lb. boiler pressure would be 12,900 lb. A smaller type is also built.

It is claimed that in passenger service the starter will eliminate starting shocks resulting from taking up slack. In freight service it will eliminate the need for taking up slack in order to get a train under way, and in so doing will reduce break-in-two's and draft-gear and coupler failures. (*Railway Age*, vol. 73, no. 19, Nov. 4, 1922, pp. 858–859, 1 fig., and *Railway Review*, vol. 71, no. 19, Nov. 4, 1922, pp. 613–615, 3 figs., *d*)

REFRIGERATION

Experiments on Ice Making—Supercooled Water

METHODS OF FREEZING RAW WATER, Halbert Paul Hill. Description of what appears to be a novel method of ice manufacture in which an attempt is made to make a practically continuous cake of ice from which pieces may be cut off as desired. The method is based on the use of supercooled water. It is known that strongly agitated water may be cooled below its theoretical freezing temperature without solidifying. In tests made by the author, water strongly agitated and surrounded by a 14-deg. fahr. brine was reduced to 26.8 deg. fahr. before it flashed and ice crystals were formed. In other experiments water was not agitated but covered with a film of oil and a temperature of 25 deg. fahr. was reached without crystals forming. A piece of ice was dropped into the water and crystals slowly formed. The peculiar thing in the formation of these crystals is that they formed in laminated sheets. After proving that water could be supercooled, a plant was built with the idea in view that if ice crystals could be made in sufficient quantities and the ice cans filled with a concentrate of ice crystals and water at 32 deg. fahr., a marked step in the development of a more commercial method of manufacturing ice would be obtained. Notwithstanding all efforts made it was found impossible to use this plant on a commercial scale as the equipment would work only a few minutes, when the cooler would freeze up. This happened even when high back pressures from 42 up to 100 lb. per sq. in. were used. The apparatus, it seems, was provided with screens of 200 mesh in the bottom of the tank to prevent the crystals from being carried to the cooler. As a matter of fact, however, the crystal formations break up into such minute particles that they readily pass through eight to ten thicknesses of 200-mesh screen reinforced with cheesecloth, and these minute crystals once in the cooler cause the flashing.

A device was then developed for separating crystals by gravity. After this separator was connected between the tank and the cooler, supercooled water could be made and maintained for an indefinite period at temperatures below 32 deg. fahr, and it was

believed that by introducing the supercooled water into a refrigerated can or receptacle the water coming in contact with the refrigerated surface would deposit laminations of ice thereon, thus removing the heat through water instead of through ice. Numerous experiments were made but without satisfactory results on a commercial scale at first. Thirty-seven forms of cans of various types and shapes were made. In all of these absolutely clear ice was made but in no case was it possible to deposit crystals that would adhere to the refrigerated surface or to the ice formed. This led to further experiments to determine the relation between supercooled water and ice crystals.

In the course of these experiments another means was employed in the hope of solving the problem. A large cast-steel ammonia-jacketed can, weighing 7000 lb., was made in two sections, machined inside and bolted together. This can was 6 ft. 9 in. long and the ammonia-jacketed section 6 ft. long. It was open at the ends and the front end was provided with a cover and an inlet and outlet; in the center an agitator was provided. The idea was to admit supercooled water into the can through the top inlet, agitate it in the can, and discharge it from the lower outlet. The object of the agitator was to mix the supercooled water and crystals so that the entire mass would be of one temperature and the crystals would be deposited on the refrigerated surface of the can and thus make ice. Means were provided to lubricate the inner surface of the can, the intention being to make ice continuously, allow it to slide out of the can as made, and then saw it off into standard lengths. The system was not a success.

Experiments are now being conducted in an attempt to make ice in an open tank, separate the crystals in the water by a centrifugal separator and then press them into a cake by means of hydraulic pressure. The crystals made from supercooled water are so minute that they can hardly be distinguished from water when in a glass, being so clear. By subjecting them to pressure, however, they can be compacted so that solid ice can be made.

In the course of these tests an endeavor was made to stabilize the crystallization point by catalytic action. Various acids and alkalies were added to the water with a view of decreasing the freezing point and with the hope of discovering some means whereby the crystal formation would be retarded. Certain dyes were used, as well as starch, glycerine, and other chemicals. A thorough study of the crystal formation of sugar, salt, glycerine, and various chemicals was made and a number of very interesting experiments were conducted with electrical apparatus. Glass containers were made surrounded by coils of wire through which both alternating and direct current were applied with a view to stimulating or directing crystallization by magnetic lines of force.

It would appear, therefore, that while no commercial result has yet been obtained from the work of the writer, some facts of considerable scientific interest have been established. (*Refrigerating Engineering*, vol. 9, no. 4, Oct., 1922, pp. 127–131 and discussion, pp. 131–132, 11 figs., *eA*)

THERMODYNAMICS OF AMMONIA COMPRESSION, W. H. Motz. Brief discussion of general thermodynamic principles followed by a derivation of the various formulas used in the design of ammonia compressors.

For the constant k in the formula for mean effective pressure where ammonia is compressed adiabatically (ratio of specific heats) the author recommends a value of 1.31. Some of the formulas are accompanied by examples and a number of curves and tables are given, among them being a table for the mean effective pressures of ammonia and curves for mean effective pressures for various suction and discharge pressures. Formulas for the mean effective pressure with and without clearance are given, and the author points out that the mean effective pressure with clearance is equivalent to the mean effective pressure without, multiplied by the clearance factor, or the volumetric efficiency due to clearance. The effective displacement of the compressor cylinder with clearance is reduced in direct proportion to the volumetric efficiency due to clearance, and the mean effective pressure of the cylinder with clearance is reduced in the same proportion. This indicates, theoretically, that the clearance does not effect the work requirements for a given amount of refrigeration. In passing, the author calls attention to the formulas and tables given by Carl J. Jefferson in an article entitled Mean Effective Pressure of Ammonia Compressors, in the Sept. 18, 1917, issue of *Power*. He claims that the formula given therein is incorrect (because it apparently assumes a 100 per cent condition the whole distance), as is also Mr. Jefferson's table of mean effective pressures with varying clearances, suction pressures, and condenser pressures. (*Refrigerating Engineering*, vol. 9, no. 4, Oct., 1922, pp. 119–124, 6 figs. and discussion pp. 124–125 and 132–133, 2 figs., *gt*)

SPECIAL PROCESSES

Dust Separation by Gravity

GRAVITY METHOD OF DUST SEPARATION, Dr. Karl Wiest. The gravity method of dust separation is still used in many instances because it is the cheapest to employ under certain conditions, and when properly applied gives excellent results. The method of operation of gravity-type dust-separation plants rests on the fact that when the velocity of the gas in which the dust is held in suspension is decreased the dust particles have time to settle out because of their higher specific gravity. The author shows that both in stationary and in moving air each particle of dust has a certain velocity of fall peculiar to itself, and establishes a law to the effect

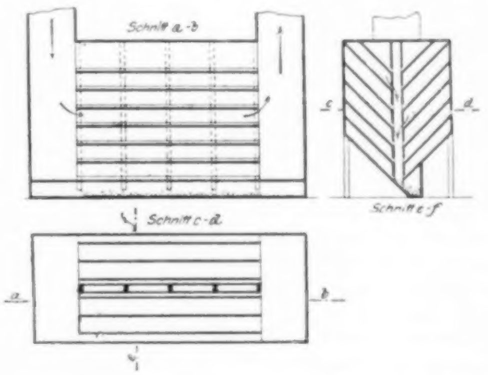


FIG. 10 DUST-SEPARATING CHAMBER WITH MULTIPLE PARTITIONS BETWEEN FLOOR AND CEILING

that *the efficiency of a dust-separation chamber is a function of its floor area*, while the height must be only great enough to prevent the flowing gases from picking up and carrying off dust from the floor. If this is so, the general opinion as to the importance in a dust chamber of sufficient *volume* would appear to be incorrect. This is of considerable importance in connection with the use of standpipes forming part of the usual air-cleaning equipment in blast-furnace plants.

In order to test out the correctness of the above rule, in a certain dust-separating chamber of rectangular cross-section a false floor was built in at half the height of the chamber over one-half of its width. If the law as to the importance of the floor area of the chamber in governing the amount of dust separated out from the air be correct, there should be deposited on each of the two halves of the subdivided chamber approximately as much dust as on the floor of the undivided half. The test proved that this is so.

Furthermore, the dust chamber with the multiple subdivision in the vertical direction as shown in Fig. 10 (patented by the author) gave a dust separation many times greater than that obtained in a simple chamber. Among other things, the author shows a smokestack where steplike baffles have been built in to modify the free flow of the gases and to force them to deposit the heavier particles of dust on these baffles.

The effect of velocity of fall on the separating out of dust particles may be utilized in the case of smokestacks delivering their gases into the open air, where, for some reason or other, excessive dust may be objectionable. A smokestack in itself is not an apparatus for the dust separation, but it may help to protect from dust the surroundings of the plant. If a particle of dust having a velocity of fall k leaves a smokestack of the height H and is immediately picked up by a wind velocity w, it is carried away for a period of time necessary to have it fall through a height H. Its distance of flight will therefore be $f = Hw/k$. The higher the smokestack

the greater the wind velocity, and the smaller k the greater will be the distance to which the particle of dust is carried. If the wind is very slight the gases, and with them the dust particles, do not spread horizontally immediately upon leaving the mouth of the smokestack, but rise more or less. If, however, the smokestack has built into it a dust-separating chamber which gives a certain velocity k', no dust particles can leave the smokestack which have a velocity of fall greater than k', and therefore the minimum distance of flight will be $f_{\min.} = 3H/k'$, the wind velocity being here assumed as 3 meters per second. As a result no dust can fall within the radius of $f_{\min.}$. (*Stahl und Eisen*, vol. 42, no. 44, Nov. 2, 1922, pp. 1650–1653, 4 figs., *de*)

Reinforced-Concrete Pipe Made by Centrifugal Process. Description of centrifugally cast concrete pipe made by the Lock Joint Pipe Co. at Ampere, N. J., and Denver, Colo. The machine used does not essentially differ from similar machinery in the Hume process (described in Mechanical Engineering, July, 1922, pp. 474–475) and in some German processes. The whirling form is of wrought iron in take-down construction and is set up around the reinforcement cage so arranged that the cast-iron joints at the end of the cage are flush with the circumference of the form. The grooves or sheaves of the form are then engaged by an endless steel cable hanging from the frame and give the form its motion.

In one respect the machine is different from the Hume, viz., in that it uses a charging bucket consisting of a longitudinally placed cylinder with a slot a few inches wide along its elements. It is completely filled with concrete through the slot and then moved longitudinally on tracks into the center of the whirling form. Once the charging bucket is inside, the form is started to whirl and the charging bucket is slowly turned over so that it discharges its concrete content uniformly along the inside of the form where it is immediately thrown outward by centrifugal force. The size of this charging bucket is so proportioned as to give the proper concrete content to form a shell of a required thickness.

After the form has been whirling for about five minutes there is inserted into the center a pan resting clear of the form at either end and projecting from the center of the form. It is used as a guide for brushes, manipulated by the attendant, which clean the interior of the pipe and collect the excess water which clings to the whirling surface. It is said that in a pipe 20 in. in diameter, $2^1/_2$ in. shell thickness, and 12 ft. long with a concrete that would be considered of normal working mortar plasticity, a full wheelbarrow load of cement, colored water and laitance is drawn off.

The concrete from which the pipe is made is a mortar rather than concrete, as it is a one-half mixture of portland cement and ordinary good, clean building sand. The finished pipe presents a remarkably uniform surface. So far no tests have been made as to their strength, but they are being used for pressures up to 50 lb. per sq. in. for the 20-in. pipe and have resisted pressures up to 200 lb. per sq. in. (*Engineering News-Record*, vol. 89, no. 80, Nov. 16, 1922, pp. 829–830, 4 figs., *d*)

STEAM ENGINEERING (See Power Plants)

THERMODYNAMICS (See Refrigeration)

VARIA

Sculpture by Camera. In the December, 1922, issue of Mechanical Engineering (p. 843) a method of portrait sculpture by the aid of photography was described by W. F. Engelmann of Chicago. It is now stated that Howard M. Edmonds, a graduate of the Massachusetts Institute of Technology, has developed another method for accomplishing the same result. In this method a lantern projector popularly known as a magic lantern throws on the face of the sitter a series of closely spaced lines. These lines projected on a screen are fine, straight parallel lines, but when thrown on the face of the subject and viewed from a certain angle they appear curved and follow the contours of the face. A photograph is then taken of the subject with these lines projected on the face with a strong light, and the negative shows the many curved lines on the face. A positive is then made from a negative and given to the operator of the carving or sculpturing machine.

Connected with the machine is a drill which can be made to rotate and also to move in a straight line and scratch thin lines on the marble or such material as may be chosen. The operator by the use of levers and handles can control the drill and make it begin and end at any point, and can also regulate the depth of cut. To secure a likeness of the model the operator manipulates a pointer which is connected to the drill so as to follow the curved lines on the photograph. As the pointer traces out the lines on the photograph the drill moves up and down, making cuts of various depth as it moves along in its straight-line path. As the lines curve in on the photograph the drill cuts deeper and as they curve out it cuts shallower, and in this way the varying contours of the subject's face are reproduced in marble. In practice it is found that polishing and a certain amount of hand carving of the hair

Fig. 11 A Bas-Relief Made by the Edmonds Photographic Process

is necessary, but otherwise the machine does the entire work of carving, and by eliminating the necessity of a skilled sculptor brings the sculptured portrait within the province of persons of moderate means. (*The Tech Engineering News*, vol. 3, no. 5, Nov., 1922, pp. 148–149, 1 fig., *d*)

German Export Policy. The more important of the German oil-engine manufacturers maintain a complete sales organization covering the entire world. For example, one prominent builder has over 400 salesmen in South America, Egypt, India, China, etc. These salesmen are not mere brokers but direct representatives, selling the builder's product and devoting their whole time to this business. If the engine sales are insufficient to give the salesmen a profitable business, the engine builder takes on some other line of machinery that can be readily sold in the territory under question. This increases the profits of the representatives and ties him still closer to the engine builder. The engines for export are finished according to the demand of the country into which they go. Local desires as to painting, extra parts, crating, etc., are complied with. In making export prices on account of exchange conditions the factory cost has but slight influence and the quoted price depends on the price prevailing in the country to which the engine is going. The extent of the German foreign trade in oil engines may be judged by the fact that in one South American country a German builder maintains a repair shop having a payroll of 40 men. (*Power*, vol. 56, no. 23, Dec. 5, 1922, pp. 878–879, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reveiwer. Opinions expressed are those of the reviewer, not of the Society.

Forty-Third Annual Meeting of the A.S.M.E.

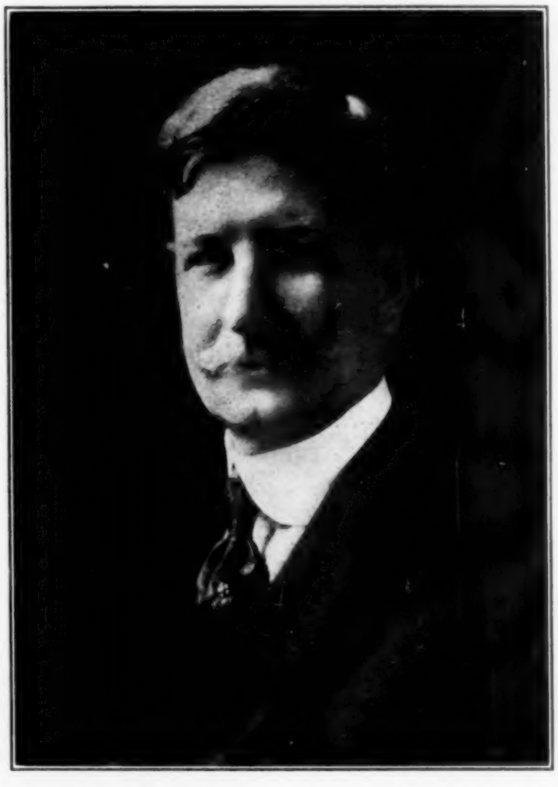
Noteworthy Week Comprising Twenty-four Sessions Dealing with Professional Subjects, Economics, and Industrial Education and Training—Local Sections' Conference a Prominent Feature

THE FORTY-THIRD Annual Meeting of The American Society of Mechanical Engineers was notable for its well-balanced, diversified program with splendid papers and enthusiastic discussion. The four days of the meeting, December 4 through 7, 1922, formed a very intense period, however, for during that time there were twenty-four sessions, fifty-three committee meetings, and four social events. This was followed by the National Exposition of Power and Mechanical Engineering which opened on Thursday, December 7, at one o'clock at the Grand Central Palace. It was a remarkable week and the 1836 who registered left the meeting with a feeling of having attended a very successful affair.

The presidential address of Dean Dexter S. Kimball attracted wide attention and gave mighty inspiration in its challenge to the engineer to assume his proper responsibility in maintaining and developing civilization. He was given an ovation at its presentation on Monday evening of the meeting. The address appears in full as the leading article of this issue.

Perhaps the most interesting session of the meeting was that on Engineering and Economics held on Wednesday evening, December 6. President Dexter S. Kimball presided over a program arranged jointly by the A.S.M.E. Management Division and the American Economic Association. Papers were presented by Dr. W. C. Mitchell on Making Goods and Making Money, and by E. M. Herr on The Human Problem in Industry; and H. R. Seager, E. F. DuBrul, F. J. Miller, and J. L. Harrington contributed to the discussion. These addresses with the discussion appear on other pages of this issue.

The Council met on Monday to transact routine business, and on Friday to install the new officers and consider questions arising from the proceedings of the business meeting. The outgoing President, Dean Dexter S. Kimball, was presented with a gavel, and the custom was inaugurated of also giving the incoming President this symbol of his authority. John Lyle Harrington was formally introduced as President; as were the new Vice-Presidents, W. S. Finlay, Jr., W. H. Kenerson, E. F. Scott, and H. H. Vaughn; and Managers, A. G. Christie, J. H. Herron, and R. V. Wright.



John Lyle Harrington — President, 1923
The American Society of Mechanical Engineers

This Annual Meeting was also the scene of a very remarkable conference of Local Sections Delegates which lasted throughout the week. On Monday the delegates met all day to talk over Local Sections problems, breaking the gathering, however, for luncheon with the Council, at which a number of inspiring four-minute addresses were delivered by the officers and chairmen of standing committees. During the rest of the week the Local Sections Delegates met with the various Standing Committees of the Society for the discussion of national Society problems, and on Friday they attended the Council meeting. In the afternoon the Council attended the final meeting of the Local Sections Delegates. As a result of this week-long conference the members of the Society from afar learned of the inspiring importance of the Society's activities. A more complete account of the transactions of the Council and the deliberations of the conference of Local Sections Delegates appeared in the December 22 issue of *A.S.M.E. News.*

Business Meeting

On Monday afternoon, December 6, the annual business session was held. Its feature was the presentation of the report of Calvin W. Rice Secretary of the A.S.M.E., on his recent trip to South America. This appears in its complete form on page 72 of this issue of Mechanical Engineering. Mr. Rice preceded this report by his customary summary of the work of the Standing Committees of the Society. The formal report of the Tellers on the ballot for the new Constitution and Code of Ethics was read. The following selection of the Nominating Committee by the Conference of Local Sections Delegates was approved: Charles L. Newcomb, Holyoke, Mass.; A. E. Allen, New York City; William H. Kavanaugh, Philadelphia; W. T. Magruder, Columbus; W. L. Abbott, Chicago; Louis Bendit, Kansas City; Sam H. Graf, Corvallis, Ore.; and alternates, L. D. Burlingame, Providence; S. H. Libby, New York City; H. S. King, Atlanta; C. W. Bennett, Columbus; William M. White, Milwaukee; L. D. Crain, Ft. Collins, Colo.; R. D. Hoyt, Portland, Ore. Announcement was made of the final approval of three parts of the work of the Power Test Codes Committee: The General Instructions, Code on Definitions and Values, and Code for Reciprocating Steam Engines. The following reports of the Research Committee were also presented for final approval: Standards on Malleable Iron Screw Fittings, Gears and Pinions for Electric Service, Gray Iron Industrial Spur Gears, Specifications for Steel Castings for Gears, Specifications for Brass and Bronze for Gears, and Specifications for Forged and Rolled Steels for Gears.

In presenting life membership to Major Fred J. Miller, resolutions of thanks from the Council were read which expressed an appreciation of Major Miller's service as president and as advisor and servant under all circumstances, not the least of which was his assumption of the burden of the secretaryship while Mr. Rice was in South America.

Life membership in the Society was also presented to Prof. R. C. H. Heck for a paper on Steam Formulas which was adjudged by the Committee on Awards and Prizes as the best one appearing in the 1920 volume of Transactions. The Junior prizes were awarded to R. H. Heilman of Pittsburgh for his paper on Heat Losses from Bare and Covered Wrought-Iron Pipe at Temperatures up to 800 Deg. Fahr., and to F. L. Kallam of Los Angeles, Cal., for his paper on The Investigation of the Thermal Conductivity of Liquids.

E. S. Carman, Junior Past-President and Chairman of the A.S.M.E. delegation to the American Engineering Council, emphasized the fact that the organization of national, state, and local societies composing The Federated American Engineering Societies is concerned more particularly with those engineering activities that are of great civic import.

L. W. Wallace, Executive Secretary of the Federation, gave a convincing report of the activities of the Federation.

Mr. Wallace called attention to the fact that in the two industrial reports which have been issued by the F.A.E.S., Herbert Hoover has written the introduction to the one on Waste in Industry and President Harding the one to the report on the Twelve-Hour

Shift in Industry. He spoke of the coöperation of the Federation with the Department of Commerce in standardization work and in adjusting the relations of the Federal Government with contractors; also of their coöperation with the Post Office Department in organizing a division for the handling of materials. Certainly the Federation has been influential in presenting certain legislative measures; and in the matter of a topographical map of the United States they have had introduced into Congress a law which will make possible the completion of this necessary map in twenty-five years instead of the one hundred years it will take at the present rate.

Following Mr. Wallace, Rudolph P. Miller gave a report on the National Board of Jurisdictional Awards in the Building Industry. This Board has been meeting on an average of four times a year and to date has rendered about 38 decisions, many or all of which have been instrumental in the settlement of industrial disputes before they have actually occurred. He urged that engineers everywhere give their support to this Board, showing that untold money may be saved for the people of this country by the elimination of the labor disputes over which the Board arbitrates. A review of the activities of this Board will be found on page 75.

Student Session

On Wednesday afternoon, December 6, Dr. William H. Kenerson presided over a gathering of representatives of Student Branches at which a number of problems relating to the activities of the Branches and their relation to the Society were given careful consideration. Addresses were made by Edwin S. Carman, Past-President, John Lyle Harrington, President-Elect; John Younger, and Calvin W. Rice. Representatives were present from the following colleges:

Armour Institute of Technology	Massachusetts Institute of Technology
Brown University	Michigan Agricultural College
Bucknell University	University of Michigan
California Institute of Technology	New York University
Carnegie Institute of Technology	North Carolina State College
Case School of Applied Science	Ohio State University
College of the City of New York	Oregon Agricultural College
University of Cincinnati	Pennsylvania State College
Cornell University	Polytechnic Institute of Brooklyn
Drexel Institute	Purdue University
Georgia School of Technology	Rensselaer Polytechnic Institute
Johns Hopkins University	Rutgers College
University of Kansas	Stevens Institute of Technology
University of Kentucky	Agri. and Mech. College of Texas
Lafayette College	Tufts College
Lehigh University	Virginia Polytechnic Institute
Lowell Textile School	Worcester Polytechnic Institute
University of Maine	Yale University

Social Events and Excursions

The meeting furnished its usual quota of valuable opportunities for good-fellowship. Although the President's Reception, usually held on Tuesday evening, was held this year on Monday, it was exceedingly well attended and an enjoyable evening resulted. The informal dinner and smoker on Tuesday evening gave the desired opportunity for the men to get together, and on Wednesday afternoon the ladies served tea. The dinner dance Thursday night was a success from every point of view.

Throughout the week an enthusiastic and capable ladies, committee was in attendance at the building and large groups of visitors were taken to the Museum of Natural History, to a private gallery of modern American paintings, to inspect the *Pictorial Review* building, the Hecksher Foundation and the Museum of the American Indian, and to a Fashion Show at Wanamaker's, where tea was served.

The more technical excursions included visits to the Hell Gate Station of the United Electric Light and Power Company, the Broadcasting Station WEAF of the American Telephone & Telegraph Company, one of the automatic exchanges of the New York Telephone Company, and the plant of the Wheeler Condenser Company at Carteret, N. J. Large groups visited the McGraw-Hill building for luncheon on Thursday, and the Battleship *Maryland* at the Brooklyn Navy Yard on Friday. A very interesting demonstration of the Christie amphibious gun mount was held on Tuesday afternoon, when this new device traveled over smooth roads on wheels, over broken country on its caterpillar tread, and then propelled itself across the Hudson.

Refrigeration Session

The first technical session of the meeting was held jointly with the American Society of Refrigerating Engineers, on Monday afternoon, December 4. Harry Sloan, President of the A.S.R.E., presided over a program of two papers. In the first paper, on the Design of Cooling Towers, C. S. Robinson[1] the author established a general principle applicable to cooling-tower design and derived equations for the use of the design. Extended discussion as to the practicability of the paper was submitted by Barton H. Coffey,[2] L. A. Phillips[3] and W. S. Grosvenor.[4] This paper will appear in abstract with the discussion in a later issue of Mechanical Engineering.

The second paper, by Percy Nicholls,[5] on the Economic Thickness of Insulation in Refrigerating Field, appeared in the December issue of *Refrigerating Engineering*. In this paper the author defines economic thickness for refrigeration as that which will reduce to a minimum the sum of the expenses due to heat passed through the insulation plus the expenses of prevention. The author discusses the factors entering into this definition, proposes a formula for determining the economic thickness of insulation, and points out some of its applications. In his conclusion Mr. Nicholls states that it has not been his purpose to recommend definite thickness but rather to establish a standard of reference and set out a basis of argument on which the figuring of thickness may be done. Neither will it be worth while to attempt in most cases to introduce refinements in calculation since corresponding close values for the various constants cannot often be predicted. Fuel prices in the future may be different and the efficiency of operation will depend on how the plant is run. It is, however, advisable to have an agreed standard method of computation to refer to in case of dispute, and on which to base practical rules, and if such agreement can be expressed as a definite formula, then the problem is reduced to fixing the values of the various symbols.

In the discussion Prof. A. J. Wood[6] stated the advantage of plotting "cost-thickness" curves. For ease in simplifying calculations, Professor Wood suggested combining the factors of interest, depreciation, maintenance, and taxes. He also suggested a chart to take care of surface effect and conduction of the structure independent of the insulation and to provide for that part of the year in which there are heat losses. He agreed with the author of the paper that the practical economic thickness is not an exact thickness.

C. H. Herter[7] pointed out the difficulty of evaluating some of the factors in Mr. Nicholls' formula and suggested some simple rules. If the average plant where the cost per ton of refrigeration amounts to about $2.50, he suggested the provision of 1 in. of pure cork board, or its equivalent, for every 15 deg. fahr. maximum air to air temperature difference. Where refrigeration is very cheap, allow 1 in. per 20 deg. maximum difference, and where refrigeration is expensive allow 1 in. for each 10 deg. maximum difference. He also suggested that for 1 sq. ft. of insulation it is proper to pay up to one-fifth or one-fourth of the total cost per ton of refrigeration. J. B. Starr[8] emphasized the need for consideration of upkeep as a factor in cost of installation.

Management Session

The Management Session, held Tuesday morning, December 5, furnished a further opportunity for a discussion of the paper by L. P. Alford[9] on Ten Years' Progress in Management which had been discussed previously before a number of Local Sections during Management week, October 16–21. R. A. Wentworth, Chairman of the Management Division, presided over this discussion as well as over the discussion of the paper by Wallace

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[7] Refrigerating Engr., Brunswick-Kroeschell Co., New York. Assoc-Mem. Am.Soc.M.E.
[8] President, Starr Engrg. Co., New York. Mem. Am.Soc.M.E.
[9] Editor *Management Engineering*, New York City. Mem. Am.Soc.M.E.

Clark on Relieving Industry of Burden, and the presentation of Progress Reports by the Committees on Standards for Graphics and Standardization of Terminology.

In introducing the discussion on Mr. Alford's paper, Fred J. Miller[1] expressed the thought that the most important progress in the ten-year period cannot be measured nor weighed as it is manifested mainly in the changed attitude of mind shown in the installation of management methods by the promotion of coöperation instead of the arousing of opposition and antagonism.

Dr. H. S. Person[2] stated as his opinion that the real measure of progress in management would be an analysis of the existence of the combination of the various management mechanisms listed in the report, which he thought to be impossible at present. He also thought that the greatest measure of advance in management, a more or less intangible but very real thing, is a new point of view, a new method of approach by management.

J. P. Jordan[3] combated the idea that cost control is a mechanism and emphasized that it is an absolutely indispensable organ of enlightened management. He decried the fact that management had failed to recognize the importance of cost control.

Dean Dexter S. Kimball[4] told of his experience in establishing a course of instruction for the fundamentals of management which he believed will be much more clearly understood during the coming years.

Dean R. L. Sackett[5] pointed out that the advance in management has been accompanied by the development of administrative engineering courses which are drawing the attention of students to the humanistic side of industrial engineering.

David B. Rushmore[6] emphasized the need for a true definition of management. He also spoke of the need for developing executives along fundamental lines as a real constructive work for industry.

L. W. Wallace[7] expressed the hope that during the next ten years management would become more informed as to the fundamental economics involved so that they can be more intelligently placed before labor and the public.

The paper by Wallace Clark[8] on Relieving Industry of Burden appeared in the December issue of MECHANICAL ENGINEERING. In his discussion Dr. Person expressed the feeling that it is important that the problem of relieving industry of burden be treated from the social point of view, which must consider the internal forces that impinge upon the individual plant and against which the management is sometimes almost helpless unless they may be modified by concerted effort. Dr. Person pointed to the joint session with the economists at this Annual Meeting as a hopeful sign that the engineer is attempting to broaden his viewpoint.

Joseph E. Pogue[9] defined the major problem for the management engineer as the formulation of an industrial policy which will require technical proficiency and economic insight involving not only a coördination and control of the internal components of the industrial units but also a synchronization of this unit with the industry at large. The big job for the future is to learn how to explore and control the industrial interstices—the inter-department, inter-company, and inter-industry spaces—which now, unmeasured and neglected, cause the major inefficiencies in our industrial system.

Fred J. Miller emphasized the importance of perfecting administrative methods first and spoke especially about the reduction of inventories by reducing manufacturing time, one of the points stressed in Mr. Clark's paper. The reduction of manufacturing time can be brought about by proper planning and routing, and by entire coöperation on the part of all individuals in the plant.

John Younger,[10] speaking from the point of view of the manufacturer, emphasized the importance of external industrial conditions effecting idleness in a specific plant.

L. W. Wallace stressed the responsibility of manufacturers to secure facts as to the need for a given commodity before money is invested in factories to manufacture this commodity.

John J. Swan,[1] representing the A.S.M.E. on the Joint Committee on Standards for Graphics, presented a progress report. The Committee has had a fairly complete bibliography prepared and a start has been made in the preparation of definitions and terminology and the presentation of chart forms. A questionnaire has been sent out to those using graphics and a great deal of valuable material has been received.

F. E. Town,[2] Chairman of the Joint Committee on Management Terminology, presented a progress report for this Committee in which was included a classification of management literature in accordance with the Dewey Decimal System. The general subject of classification was given consideration and it was the consensus of opinion that classification procedure should be inaugurated and changed as occasion warrants.

Session on Ash Handling

THE MATERIALS Handling Division arranged the program for the Session on Ash Handling on Tuesday, December 5, over which H. V. Coes, Chairman of the Division, presided. The program consisted of a paper by John Hunter and Alfred Cotton which described systems of ash handling for marine and stationary work. The discussion presented some added material about ash-handling methods which was of particular importance as an expression of the point of view of operating engineers. An abstract of the paper with an account of the discussion will appear in the February issue of MECHANICAL ENGINEERING.

Machine Shop Session

FIVE papers were presented at the Machine Shop Session on Tuesday, December 5, at which F. O. Hoagland, Chairman of the Machine Shop Division, presided. The paper by F. E. Cardullo[3] describing a new system of Helical Involute Gearing for Use in Metal Planers appeared in abstract in the December issue of MECHANICAL ENGINEERING. In the discussion of this paper F. K. Hendrickson[4] agreed with Mr. Cardullo as to the unquestionable need of helical gears for planer drives with a consequent reduction in chatter marks and machine vibration. Mr. Hendrickson also spoke of the advantage of the helical driving gear in reducing the tendency to lift when heavy cuts are being taken. Charles Meier[5] expressed the opinion that Mr. Cardullo's form of gearing increased the friction losses and end thrust. He was also of the opinion that greater accuracy may be required in mounting this system of gearing. G. M. Eaton[6] spoke of his experience with helical gears on railway work, telling especially of one gear that after 60,000 miles of operation was superior to a spur gear, although the drive possessed less efficiency.

Mr. Estabrook's paper on Testing Involute Spur Gears appears in abstract in this issue of MECHANICAL ENGINEERING and the discussion on it follows thereafter.

The paper on Spherical Gears by Charles H. Logue appeared in full in the November issue of MECHANICAL ENGINEERING. There was no discussion on this paper.

The remaining papers were by Walter Ferris,[7] on Application of Hydraulic Transmission Variable Speed Drive to Machine Tools and Manufacturing Processes, and by Fred A. Parsons[8] on the Power Required for Removing Metal. Mr. Ferris' paper will be abstracted in a future issue of MECHANICAL ENGINEERING and will be accompanied by the discussion. Mr. Parsons' paper appears in abridged form in this issue.

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[4] Chief Mech. Engr., Reed-Prentice Co., Worcester, Mass.
[5] Treasurer and Works Manager, The Acme Machine Tool Co., Cincinnati, Ohio.
[6] Chief Mech. Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
[7] Vice-President, The Oilgear Co., Milwaukee, Wis. Mem. Am.Soc.M.E.
[8] Chief Engr., Kempsmith Milling Machine Co., Milwaukee, Wis. Mem. Am.Soc.M.E.

Session on Education and Training

AT THE Session on Education and Training for the Industries held Tuesday, December 5, the program was presided over by W. W. Nichols, Chairman of the Committee on Education and Training for the Industries. The presentation of the subject was in the form of a report of the Committee which was introduced by Mr. Nichols. The report itself consisted of three parts, one on Extension and Correspondence Schools, by James A. Moyer;[1] a section on Industrial Education as Represented in Schools, by C. R. Richards;[2] and the final section on Schools for Apprentices and Shop Training, by R. L. Sackett.[3] Each of the sections of this report were presented separately and discussed. The report of the Committee with a complete account of the discussion will appear in the March issue of MECHANICAL ENGINEERING.

Research Session

A GROUP of five notable papers resulting from the activities of the Research Committee were presented at the Session on Tuesday afternoon, December 5, with Walter Rautenstrauch, Chairman of the Research Committee, as presiding officer.

In his paper entitled A New Method of Determining the Effect of Speed upon the Strength of Gear Teeth, Wilfred Lewis[4] discussed the analytical work on this subject performed by Oscar Lasche, Professor Marx and C. H. Logue, and described a modification of his gear tester as a device for measuring exactly the relation of speed to pressure. This paper appeared in the December issue of MECHANICAL ENGINEERING. The discussion, which was contributed by Messrs. E. D. Church, Carl G. Barth and G. H. Marks substantiated the need for further investigation of this subject.

The report of the Research Sub-Committee on Sudden Initial Pop Lift of Safety Valves removed the fear that a relatively large sudden steam discharge from the boiler or the sudden stopping of such a discharge may cause dangerous shock to the boiler.

The Committee which was made up of P. G. Darling, Chairman, E. F. Miller, W. E. Jerauld, G. H. Clark, I. E. Moultrop, A. M. Houser, A. L. Fitch, and G. S. Coffin, conducted two series of tests, one at Boston with the work carried on by three thesis men at the Massachusetts Institute of Technology, and one at Bridgeport.

In the tests an extremely sensitive pressure indicator of special design was used which employed a thin diaphragm with a maximum allowable movement of 0.007 in. This diaphragm was balanced between the pressure of the steam or water in the boiler and an outside air pressure. Any change in pressure would cause a movement of the diaphragm which could be detected by a microphone or an electric light. In the Bridgeport, tests which were conducted on a 94-hp. B. & W. water-tube boiler at 300 lb. pressure, the Committee selected four points at which shock on sudden relief of steam would be most likely to occur as follows:

- *a* At the upper or front ends of the tubes where the water in circulating takes nearly a right-angled turn into the front header
- *b* At the top of the front header where it enters the drum
- *c* Against the headers of the drum
- *d* At the middle of the drum.

The quick-opening test valve was arranged so that the discharge of steam could be varied from six to seventeen times the capacity of the valve assigned in the A.S.M.E. Boiler Code. The test showed, however, that even with steam discharging from the valve at the maximum rate of 95,000 lb. per hr. there was no indication of change in pressure from any of the four pressure indicators. The closing paragraph of the report is as follows:

> This investigation might be continued with prolonged trials on different types of boilers, under different conditions of steaming, and with additional points of attachment for the diaphragm indicators. However, considering the fact that no degree of pressure increase or shock whatever has been detected under the severe steam-discharge conditions tried, we believe that it is extremely unlikely that any boiler conditions would be found so radically different as to produce a shock. In other words, if a pressure-increase shock could be produced by any reasonable boiler operation, we believe that the conditions of our tests were representative enough to have detected at least some trace of such shock.

The only discussion on this report consisted of expressions of relief that no conditions of shock were set up upon the opening of safety valves.

The paper on Torsion of Crankshafts, by S. Timoshenko,[1] resulted from the work of the Committee on Stresses Due to the Vibration of Shafting. This paper will appear in abstract in a later issue of MECHANICAL ENGINEERING. There was no discussion.

The two papers on flow of gases, one entitled The Effect of Pulsations on the Flow of Gases, by Horace Judd[2] and D. B. Pheley,[3] and the other on Orifice Coefficients, by J. M. Spitzglass,[4] were related to the work of the Sub-Committee of Research on Fluid Meters. Abstracts of these papers with the discussion will appear in later issues of MECHANICAL ENGINEERING.

Steam Table Research

PROFESSOR A. G. Christie presided over an exceedingly interesting session on Tuesday afternoon, December 5, at which the problems and progress in research work were discussed. George A. Orrok, Chairman of the Executive Committee of the Steam Table Fund, told of his correspondence with physicists and engineers in France and England to secure interest in further research on this subject in those countries, and to develop all possible sources of information so that the tables when finally completed will be ready for adoption internationally. Dr. Harvey N. Davis told of the work being carried on at Harvard on the Joule-Thomson effect and introduced Dr. R. V. Kleinschmidt who is conducting this work. Dr. Davis also read a report from Dr. Frederick G. Keyes, of the Massachusetts Institute of Technology, who is preparing to handle one phase of the research. Dr. N. S. Osborne, of the Bureau of Standards, told of the preliminary study that is being made of the calorimetry of fluids as the basis of part of the program the Bureau of Standards will carry on.

The proceedings of this session are being more carefully prepared for publication at a later date.

First General Session

AT THE First General Session Tuesday, December 5, at which Arthur L. Rice, Vice-President of the Society, presided, three papers were presented. The first paper, by W. L. Wotherspoon,[5] on Refinery and Rolling Mill for Monel Metal at Huntington, W. Va., describes the steps taken in selecting the site for the location of the mill. The paper also deals with the layout of the plant, emphasizing some features of design of particular interest. There was no discussion on the paper. It will appear in abstract in a future issue of MECHANICAL ENGINEERING.

The second paper, by E. W. Noyes[6] and H. V. Sturtevant,[6] entitled The Size of Dry-Vacuum Pump to Employ in a Given Case, proposed a rapid method for this determination. This paper will appear in abstract in a later issue of MECHANICAL ENGINEERING with the discussion thereon.

A description of the Diesel Engine Used in German Submarine "U-117," prepared by William H. Nicholson,[7] was presented by L. H. Morrison. This will also appear in abstract in a later issue of MECHANICAL ENGINEERING.

Session on Stokers

THE STOKER Manufacturers' Association coöperated with the Fuels Division of the A.S.M.E. in preparing the program of the Symposium on Stokers which was held Wednesday morning, December 6. Professor Breckenridge presided over the

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[3] Jr. Engr. U. S. Coast & Geodetic Survey.
[4] Vice-Pres. Republic Flow Meters Co., Chicago, Ill. Mem. Am.Soc.M.E.
[5] Construction Engr., International Nickel Co., New York, N. Y. Mem. Am.Soc.M.E.
[6] Sales engineers, Sullivan Machinery Co., Chicago, Ill.
[7] Designer, Engrg. Dept., Westinghouse Elec. & Mfg. Co., Camden, N. J.

presentation of the following papers: Development and Use of the Modern Chain Grate, T. A. Marsh; Overfeed Stokers of the Inclined Type, G. I. Bouton; Design and Operation of Underfeed Stokers, H. F. Lawrence; and Chronological History of Stoker Development to the Present Day, A. H. Blackburn. The first three of these papers are abstracted on pages 14 to 21 in this issue of MECHANICAL ENGINEERING and are followed by the discussion.

Railroad Session

VOLUMINOUS discussion was brought out at the Session of the Railroad Division on Wednesday, December 6. James Partington, Chairman of the Railroad Division, presided over the presentation of three papers, one by G. H. Hartman[1] on Steam Distribution in the Locomotive, one by F. H. C. Coppus[2] on Mechanical Draft for Locomotives, and one by R. Eksergian[3] on Stresses in Locomotive Frames.

Mr. Hartman's paper appeared in abstract in the December issue of MECHANICAL ENGINEERING. O. W. Young[4] submitted a lengthy written discussion in defense of the steam distribution accomplished by locomotive valve gears of all recognized designs. He came to the conclusion that there is a practical necessity in locomotive engines for moderately large cylinder clearance, variable points of release, variable points of closure and variable points of pre-admission. He presented an indicator diagram showing steam distribution by comparing the results of the Pilliod valve and the conventional valve, and questioned whether the factors determining cutoff, release, etc., will not necessitate the readjustment of valve events to approximately the same points in the cycle that existing locomotive valve gears now place them. In closing he stated that practical refinements in locomotive steam engines must be limited to greater accuracy in registering valve events for prolonged service periods and increased port and passage areas proportioned to increases in cylinder sizes.

J. J. Jones[5] stated that in his opinion the defects of the locomotive valve gear are much exaggerated. He questioned whether any improvements in the device described by Mr. Hartman would be sufficient to warrant the additional cost of the device.

After a brief review of the steps in the progress of steam-locomotive development, L. D. Freeman[6] stated that by no line of reasoning can the quality of the steam entering the cylinder have any bearing upon the events produced by purely mechanical movement of the valve arrangement. Mr. Freeman suggested as proper steps in improving locomotive cylinder performance the separation of the action of the steam side of the valve from the exhaust side and the adjustment of the steam clearance space to properly absorb the inertia of the reciprocating parts.

H. B. Oatley[7] criticised the author's derogatory treatment of arches, feedwater heating and superheating and presented a table giving the per cent of water and fuel saving for superheated steam at several temperatures for various cutoffs and pressures as compared with dry saturated steam. Mr. Oatley called attention to the fact that in spite of the large amount of heat required to produce a pound of superheated steam over that required to produce a pound of saturated steam, the net savings are more than could be expected from any change of steam distribution.

H. H. Vaughan[8] questioned the treatment by Mr. Hartman of the subject of cylinder condensation and the effect of clearance. Mr. Vaughan called attention to the large amount of experimental and theoretical work which has been done on the locomotive in the past twenty years which does not seem to be reflected in the statements in Mr. Hartman's paper.

R. C. H. Heck[9] compared the Pilliod valve to the old Meyer gear.

The paper by R. Eksergian on Stresses in Locomotive Frames is a preliminary analysis of the major reactions brought on the locomotive frame as well as of the nature of frame action as regards variation of bending moment, shear, etc., for definitely supported types of frames. The first section of the paper is a careful analysis of the various methods of equalization, spring design, and the nature of cab supports in electric locomotives. This is followed by a section dealing with the dynamics of the steam locomotive where the variation of torque and a quantitative investigation of the various oscillations are discussed in detail. Further, a careful analysis of the variation of side-rod loads and journal-bearing loads is included. The succeeding section deals with electric-locomotive drives and the major reactions brought on the frame. This section includes the dynamics of the electric side-rod drive, which discussion augments the previous one on side-rod loads in steam locomotives. The next section discusses the dynamics of braking, its change in load on the equalization and the reactions brought on the frame. In this section is included a brief discussion of bumping loads and dynamical loads on the drawbar. Finally the nature of the lateral reactions and the dynamics of lateral oscillations on entering a curve, etc., are discussed, a short recapitulation of the static reactions while on a curve being also given.

Due to delay in the preparation of advance copies of this paper it was not possible to secure proper discussion on such a highly complicated subject. It is planned to have the paper submitted for discussion at a later meeting.

W. E. Woodard,[1] Chairman of the Research Committee of the Railroad Division, emphasized the importance of the paper as the basis for experimental research on frame stresses. Other comments were made by A. H. Houston, George M. Eaton, Selby Haar, Clement F. Street, and W. E. Simons.

The paper by F. H. C. Coppus on Mechanical Drafting of Locomotives was also well discussed. This paper will appear in a later issue of MECHANICAL ENGINEERING with an abstract of the discussion.

Second General Session

THE SECOND General Session of the meeting was held on Wednesday morning, December 6, under the chairmanship of Walter S. Finlay, Jr. Three papers were presented. Stresses in Cylindrically Shaped Rotors of Uniform Diameter, by C. M. Laffoon,[2] developed a general theory and analyzed mathematically the stresses in cylindrical rotors of uniform diameter such as are commonly associated with different classes of machinery. This paper with its discussion will appear in complete form in Transactions.

The second paper, on the Design of Flywheels for Motor-Driven Impulse Machines, prepared by C. O. Rhys,[3] was presented by S. C. Stovall, of Atlanta. In his paper Mr. Rhys analyzed the torque and speed curves for such machines and derived expression by which the characteristics of these curves may be determined. This paper with its discussion will also appear in Transactions.

The paper, on Stress Distribution in Electric-Railway Motor Pinions, by Dr. Paul Heymans[4] and A. L. Kimball, Jr.,[5] described the photo-elastic method by which this stress is determined. The paper also reported and discussed the causes of rupture of gear pinions in electric railway motors. An abstract of this paper with discussion will appear in the February issue of MECHANICAL ENGINEERING.

Power Session

FIVE papers were presented at the Power Session on Thursday morning, over which John H. Lawrence, Chairman of the Power Division, presided. The paper on The Commercial Economy of High Pressure and High Superheat in the Central Station, by Geo. A. Orrok, appeared in MECHANICAL ENGINEERING for December. A running account of the discussion of this paper is given below. The paper by Linn Helander on Feed Heating for High Thermal Efficiency will appear in the February issue of MECHANICAL ENGI-

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[6] Asst. Supt. M. P., Seaboard Air Line R. R., Portsmouth, Va.
[7] Chief Engr. Superheater Co., New York City. Mem. Am.Soc.M.E.
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NEERING, but a brief abstract of the paper and discussion is included in the present account of the meeting. An extended abstract of Paul W. Thompson's paper giving the results of tests on different types of baffling in a Type W Stirling boiler appears in this issue and is followed by an abstract of the discussion it elicited. The papers by Sabin Crocker and S. S. Sanford on The Elasticity of Pipe Bends and by B. N. Broido on High-Temperature and High-Pressure Steam Lines, together with the discussions thereon, will appear in abstract in future issues. Mr. Broido's paper was presented by title and will be discussed at the January 4 meeting of the Metropolitan Section, A.S.M.E.

Discussion of Paper by Geo. A. Orrok on The Commercial Economy of High Pressure and High Superheat in the Central Station

The discussion of Mr. Orrok's paper and its appendices on the properties of metals at high temperature and the cost of piping materials by W. S. Morrison, was opened by John A. Stevens[1] who presented by means of lantern slides data on the influence of coal cost and load factor on the efficiency and first cost of a power plant. Comparing a refined design, 15,000 B.t.u. per kw-hr., with an original design, 20,000 B.t.u. per kw-hr. and costing $100 per kw., his figures showed that with a 40 per cent load factor the increase in permissible cost in the refined design varied from 6.9 per cent with coal at $2 per ton to 69 per cent with coal at $20 per ton, while these percentages would be 10.3 and 103.3 if the load factor were 60 per cent.

Henry B. Oatley[2] questioned the correctness of assuming a turbine efficiency of 78 per cent with pressures as high as 1200 lb., saying that the increase in density at this pressure would result in greater friction losses in the turbine. He also pointed out that the specific heat transfer from the inner wall of a superheater to the steam decreased with the density and velocity of the steam. It was therefore not possible, he wrote, to produce a total steam temperature of 1100 deg. without considerably increasing the temperature of the metal tube wall. The only known means of holding down the excess of metal temperature was the employment of much higher steam velocities and pressure drops, the use of small tubes, and the restratifying of the steam during the superheating processes so as to mix the denser core with the more rarefied stratum in contact with the tube wall.

C. H. Smoot,[3] in a written communication, compared the relative advantages of increased pressure versus increased temperature and showed that at present the greater advantages lay with the former. He also pointed out that the regenerative cycle should be given more careful study. In his opinion the present type of turbine was not suited to this cycle, and his reasons formed a part of his discussion. He thought that an extension of our knowledge of the properties of steam at high pressures might indicate an even greater improvement in thermal economy by the use of high-pressure saturated steam than was now deduced from our inaccurate data.

Walter J. Wohlenberg[4] presented a written discussion which included a revised table of results (author's Table 1), the comparisons in which were based on the single-stage regenerative or heat-balance cycle of the modern power plant instead of the Rankine cycle used by the author.

I. E. Moultrop[5] said that while he was not as optimistic as the author that the manufacturer would be able to build apparatus for such high pressures as those considered in the paper, he did feel that the boiler and turbine could be built without great difficulty. The piping and valves between these two units, he said, would give considerable trouble. He concurred heartily with the author's fourth conclusion that there was more economy to be gained by close study of operation and construction losses than in an attempt to increase widely the temperature range of heat cycles.

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Peter Junkersfeld[1] said that the final question with any central station was always, Does it pay? In discussing the curves of the author's Fig. 2, especially that called "Extra fixed charges per kw-hr.," he showed that the determining factor of this item was the generator capacity factor. This factor, which was the ratio of the actual output to the possible output of a steam turbine as rated and all its accessories when averaged over a period of years, was much less than usually supposed, especially among central stations which had a substantial annual average increase in output.

An examination of the experience of 7 companies with 14 power stations and 92 steam turbines, aggregating 1,730,000 kw. rating, showed that in substantially the same 12 months' period one had had an average generator capacity factor on all its turbine units of 44 per cent and another of 25 per cent. The extra fixed charges per kw-hr. for the latter would be almost double that for the former.

An average experience curve for these 7 companies, all in large and growing cities, indicated a capacity factor of about 58 per cent on turbines one year old and 30 per cent or less on turbines ten years old.

The falling off with age of the capacity factor of turbines reflected good operating procedure with improved equipment in the successive installations. The fact that only one company operated its one-year-old turbines at 77 per cent, another at 52 per cent, and the third at only 23 per cent, and that the average of 10 turbines 2 years old operated by 6 companies was only 50 per cent, indicated that there was still very great room for improvement in construction and operation of equipment with what might today be called moderate pressures and superheat.

In all of the foregoing, wherever reference was made to turbine experience it meant not only the turbine proper, but also on one end the condensing equipment, piping and other mechanical accessories, and on the other end the generator, the excitation, the switching equipment and other electric accessories.

The development toward higher steam pressures and superheat had been under way many years and would inevitably continue. It should be given every reasonable encouragement consistent with established scientific facts and sound economic possibilities. It should be remembered however that this development in the past in a broad and overall aspect had tended toward lower construction as well as lower operating costs of the station. The development now immediately before us seemed to tend toward higher costs of construction and of operation with the exception of fuel. It thus would become even more necessary than heretofore to determine proper balances between fuel saving and what Mr. Orrok had called "extra fixed charges per kilowatt-hour." The latter was, therefore, particularly important and especially because experience had shown that it varied so widely from turbine to turbine from station to station, from company to compnay or city to city and from year to year.

A. M. Houser[2] presented a written discussion in which he pointed out that the values given by the investigations by Crane Co. on cast steel should be considered conservative.

Henry D. Hibbard[3] sketched briefly the behavior of boiler steel when subjected to increase of temperature. The paper, he said, gave a partial résumé of the properties, at elevated temperatures and for a limited time, of metals which would be employed in superheated-steam containers contemplated by the paper, but no one, so far as he knew, had investigated how the properties of such metals would be affected by long use in boilers for making highly superheated steam and in apparatus for handling it.

V. T. Malcolm[4] contributed an illustrated discussion, too extensive for abstract here, on metals for valves.

D. S. Jacobus[5] said that, speaking from the boiler maker's standpoint, pressures up to 1200 and even 1500 lb. might be attained, whereas there were special features of design that had to be carefully considered when it came to the construction of a unit

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of large size for power-plant work and no large-sized units for these pressures had so far been constructed. He agreed with Mr. Orrok that temperatures up to 750 deg. should not be exceeded. He spoke of the difficulties of designing fittings, particularly flanges for such pressures and expressed the opinion that it would seem best in the design of flanges to make the bolts the weaker element as in case of overstrain they could be readily replaced, whereas should the bolts be made strong enough to dish and distort the flanges, the flanges would have to be replaced. He also stated the need of data to show whether the elastic limit of steel at high temperatures would be permanently elevated in the case of an overstrain in the same way as at ordinary temperatures. Experiments on this feature would be most useful. He reviewed the experiments on high-pressure boilers made by Perkins and published in a book by Galloway in London in 1830.

H. L. Whitney[1] said that there had been built and kept in operation for over two years a pipe line on 1500 lb. and 850 deg. fahr. The largest point was 36 in. in diameter. There was no trouble with steam piping from increased pressure he, said, if the temperature was kept below 700 deg. fahr.

Robert Cramer[2] pointed out the relative theoretical advantage of raising pressure rather than temperature.

Max Toltz[3] said that there was a middle course between high and low pressures and temperatures of steam which was to be found in the use of resuperheated steam between stages. He had seen an experimental plant in Europe in which the economies were very high.

Francis Hodgkinson[4] said that manufacturers were embarrassed by lack of standards for pipes for the higher pressures and urged the Society to undertake the formation of such standards. He thought that the tendency to use alloy steel for bolts was unfortunate because of the danger of mixing such bolts with those of commercial steel when dismantling machinery.

Nevin E. Funk[5] spoke of some of the difficulties of operating a high-pressure power station.

Oscar F. Junggren[6] said that the discussion of high pressure was not new. As had been said, if high pressure did not pay it was useless. There had been in the past a gradual increase in pressures, each accompanied by a development of apparatus, and every increase had paid so far. Why, therefore, doubt that there could be further gain? Until some one gave higher pressures a trial, he said, no one could know what the efficiencies might be.

T. E. Keating[7] wrote that granting that the gains in individual apparatus, desirable as they might be, must be relatively small, then improved thermal efficiency of steam stations must depend upon:

1 The use of regenerative cycles which would divert from the turbine the latent heat of part of the steam, thus reducing the losses to the condenser
2 The use of heat-reclaiming apparatus for eliminating losses in the flue gases
3 The utilization of a greater range of the heat cycle.

Referring to the paper by Messrs. Orrok and Morrison, and particularly to the appendix including test data on metals under high temperatures, it was evident, he wrote, that an increase of the temperature range was today more of a problem for the chemical and physical laboratories than for central stations, as modern stations had nearly reached the limits for materials now commercially applicable.

The use of the high pressure range of 1200 to 1500 lb. suggested by the paper, he wrote, would require some new principles of turbine design, as with present designs it was probable that a greater efficiency would be obtained with 500 lb. pressure and 280 deg. superheat than with 1500 lb. and 150 deg. superheat, both conditions being equivalent to a total steam temperature of approximately 750 deg. The selection of a proper pressure and temperature depended upon combined commercial and engineering judgment applied to the problems surrounding the particular station involved, but a discussion of this factor would be of value.

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Discussion of Paper by Linn Helander on Feed Heating for High Thermal Efficiency

In order to make the discussion intelligible to those who did not attend the meeting and who have not obtained a copy of the pamphlet, we present the following brief summary of Mr. Helander's paper.

The author investigates the problem of determining the correct feedwater temperatures for conditions of high thermal efficiency. For illustrative purposes he bases his calculation upon several assumed stations of 25,000 kw. capacity using various methods of feedwater heating. The steam conditions assumed for all plants are steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on main unit, 29 in. To illustrate the influence of factors such as the water rate on the main unit and the slope of the Willans line of this unit, the Rankine-cycle efficiency of the bled steam and the Rankine-cycle efficiencies of the house turbine, two cases—designated Case 1 and Case 2 respectively—are worked out for each arrangement of feedwater heating. In the various solutions arrived at by the author the feedwater derives its heat from three possible sources: (*a*) the feedwater of the main unit is used as the condensing water of the house turbine, thereby absorbing all the heat in the steam exhausting from the house turbine; (*b*) steam is bled from the main unit in such quantities and at such temperatures as to increase the amount of heat delivered to the feedwater by the house turbine, and (*c*) before entering the boiler the feedwater may pass through the economizer.

Under Case 1 the Rankine-cycle efficiency for the bled steam based on the steam pressure on the turbine side of the throttle was approximately 67 per cent, the slope of the Willans line was 12 lb. per kw-hr. and the water rate of the main unit when carrying the gross station load was 10.6 lb. per kw-hr. The combinations of feedwater heating investigated under Case 1 included single- and double-stage heating and were as follows. For single-stage heating (*a*) no economizers, no bleeding, 1600-kw. house turbine, (*b*) no economizers, bleeding, 650-kw. house turbine; (*c*) 50 per cent economizer surface, bleeding, 650-kw. house turbine; (*d*) 100 per cent economizer surface, bleeding, 650-kw. house turbine. The greatest thermal efficiency is obtained with the last of these combinations and at a feed temperature of approximately 180 deg. fahr.

For double-stage heating and for approximately the same combinations of apparatus supplying the heat, with the exception of the substitution of a 1400-kw. house turbine for the 1600-kw. turbine and of economizers of slightly different area, the same general conclusions are drawn: that is, that the best combination is obtained with the maximum economizer surface, the maximum amount of bled steam, and the smaller house-turbine unit. For the cases investigated the feedwater temperature for best economy lies between 180 and 220 deg. fahr.

Single-stage, double-stage, and four-stage heating are worked out for Case 2 in which the Rankine-cycle efficiency of the bled steam is 80 per cent, the slope of the Willans line 9 lb. per kw-hr. and the water rate in the main unit 10.26 lb. per kw-hr. In general the same combinations of feed-heating apparatus were used with Case 2 and the results for single-stage, double-stage, and four-stage heating show that maximum economy is obtained with a maximum economizer surface, a maximum amount of bleeding, and the use of the smallest house-turbine unit. The feedwater temperatures for Case 2 are for single-stage heating, 160 deg., for double-stage heating, between 160 and 200, and for four-stage heating, between 190 and 220 deg.

The author devotes two paragraphs to discussing the effect of air preheaters, but does not bring these effects into his numerical calculations.

In conclusion he says that so many factors enter into the determination of the proper feedwater temperature that figures determined for one station should not be applied to another. The temperature should be lower for plants using single-stage heating than for those using multiple-stage heating and also should be lower for plants using economizers than for plants not using economizers.

Efficiencies of auxiliary apparatus as well as of the main generating units have their influence. If the feedwater temperature be raised much above 212 deg. fahr., factors incident to the use of pressures well above atmosphere in the auxiliary exhaust piping come into play. The proper feedwater temperature is dependent somewhat upon the initial steam pressure and temperature and on the temperature of the condensate, increasing as these increase. It is quite impossible, therefore, to determine, except within wide limits, feedwater temperatures applicable to all plants, and the purpose of the paper has been rather to indicate in a broad way the effect of feedwater temperatures on power-plant efficiency, leaving out the matter of costs, and to give some basis for estimating the sacrifice in fuel made to assure practicable operation of the feedwater-heating system as laid out for a particular station.

The discussion of the paper was opened by George G. Bell[1] who said that about a year ago he had made a study of the heat balance of the Windsor Station of the West Penn Power Co. and at that time had determined 210 deg. to be the most economical feed temperature. The turbine was a 30,000-kw. G. E. unit, the boilers 1450 hp. and the economizers had 8341 sq. ft. of surface. Two-stage and three-stage heating were studied after Mr. Helander had begun the preparation of his paper and the results, with economizers, of one-, two- and three-stage heating produced curves practically parallel with the author's: about 1.75 per cent above. These results showed a saving of about one per cent, comparing two- with one-stage heating, and about one-half of one per cent, comparing three- with two-stage heating. The temperatures he obtained did not check as closely as those obtained by the author. They were, with economizers, 200 deg. fahr. for one-stage, 235 for two-stage, and 270 for three-stage heating. Without economizers they were 265 deg. fahr. for one-stage, 290 for two-stage, and 310 for three-stage heating. The savings without economizers were about $1^1/_2$ per cent between one- and two-stage, 0.8 per cent between two- and three-stage, and 0.5 per cent between three- and four-stage heating. These two studies, he said, would indicate that even with economizers the feed temperature should be at least 210 deg. fahr.

T. E. Keating[2] read a discussion in which he said that it was somewhat surprising to find that in the application of economizers with 350 lb. boiler pressure and stage heating the most efficient temperature was close to 200 deg. fahr., as it had been rather generally believed that the efficient use of economizers demanded a somewhat lower temperature. The use of multi-stage heating was receiving considerable attention, he said, in central-station engineering, and its application involved many practical problems. He also discussed the question of the exhaust pressure at which the house turbine should be operated, and the preheating of air.

W. M. Keenan[3] spoke of some studies of bleeding at one point which had been made in connection with a new Brooklyn station. The results were surprising in that they showed that the best point to bleed the turbine was not in the vacuum range, as had been supposed, but at about 25 lb. absolute pressure. Continuing the studies to include bleeding at two points showed that best conditions prevailed with bleeding at 12 lb. and 100 lb. absolute pressure.

Prof. A. G. Christie[4] said that he was becoming convinced heating should be done by the steam from the main unit and the power should be generated by it, thus doing away with the house turbine.

Oscar F. Junggren[5] reiterated Professor Christie's statement and pointed out a further advantage in bleeding the main unit in that the more congested low-pressure end of the turbine was relieved thereby.

Francis Hodgkinson[6] said that he was surprised that the author had laid so much stress on the relations of the house turbine, because the house turbine was not going to be used very much in the future on account of the greater efficiency of the main unit and the greater efficiency of bleeding from it for feedwater heating.

Nevin E. Funk[1] said that while stage heating might prove to be more efficient theoretically, it would involve greater complications in the power plant. Simplicity made for more efficient operation, and a scheme which had great theoretical advantages on paper might not prove so in actual operation because the human element would have to be considered.

F. H. Rosencrants[2] presented a written discussion in which he showed, using the author's assumed condition, that the theoretical Rankine efficiency would be 35.35 per cent, while that of the Carnot cycle would be 40 per cent. Assuming it possible to approximate the Carnot cycle as readily as the Rankine, he showed that the saving by attempting the former ideal would be 13.15 per cent compared to the latter. He spoke further of the tendency of many engineers to ignore the superiority of the Carnot cycle over the Rankine. Accepting the figures given in the papers, he said, led one to question whether an economizer had a place in a central station of modern design with multi-stage bleeding, in view of the fact that a multi-stage bleeder heater system and additional boiler surface was likely to be less expensive than the economizer installation.

C. M. Hardin[3] wrote that every one concerned with steam-power generation realized that reliability was of first importance and must be obtained even at the sacrifice of plant efficiency and other requisite factors. Without discounting reliability, it was, however, vitally important that high efficiency be obtained. To obtain maximum plant efficiency every integral part of the station equipment must be of such correlative design and construction as would individually produce and maintain high efficiency. Stage bleeding from the main prime mover was, without question, the method that did give highest feedwater heating efficiency as compared to using the house turbine or other steam-driven auxiliaries. If stage bleeding should even in the slightest degree tend toward unreliability as regards continuity of service, the problem was to perfect the equipment used and allied with the scheme.

Session on Standardization

THE Session on Standardization, consisting of a program prepared by the Standing Committee of the A.S.M.E. on Standardization with the coöperation of the American Engineering Standards Committee, was held Thursday, December 7, with E. C. Peck, Chairman of the Standardization Committee, acting as presiding officer.

The first paper, by William J. Eynon,[4] was a progress report on the Program for the Standardization of Paper and Printing Machinery in which the new A.S.M.E. Committee on Printing Machinery is keenly interested. Mr. Eynon's paper, which was presented by Winfield S. Huson,[5] indicated the possibilities of standardization of printing presses, of which there were over two hundred sizes and styles in use today, and of folding machines with six hundred sizes and types. The first step in this simplification was a reduction in the number of sizes and grades of paper and Mr. Eynon told of the coöperative work being carried on by printers, printing-machinery manufacturers, lithographers, purchasing agents, and advertisers to secure the adoption of standard sizes of paper.

R. E. Rindfusz[6] expanded one phase of Mr. Eynon's paper by stressing the importance of reducing the number of items of paper as an important step in reducing idleness in paper-making machinery. He also pointed out that the important field for standardization was that of grade and trade names. This lack of fixed grade meant a multiplicity of brands with little or no difference. The addition of each brand of paper with its ramifications of color, sizes, weights and finishes meant an increase of 108 items with consequent increased complications in paper manufacture. Mr. Rindfusz commended the work of the Committee which was

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[4] Chairman of Standardization of United Typothetae of America, Washington, D. C.

[5] Consulting Engineer, New York City. Mem. Am.Soc.M.E.

[6] Secy., American Writing Paper Co., Holyoke, Mass.

carrying out the standardization program in a fair-minded, broad-gaged constructive manner.

W. C. Glass[1] also emphasized the importance of standardization of grades of paper as a step toward simplicity in selection of paper, fairness in competition, and simplification in the manufacturing processes.

F. A. Curtis[2] told of the coöperative work being carried on by the Bureau of Standards to secure simplification and standardization.

F. B. Gilbreth[3] bespoke support for standardization in any field as a step in developing industry. Mr. Kalkoff told of the progress which had already been made in the standardization of type and stated that the over-equipment in the printing industry in New York State was about 75 per cent and throughout the country about 150 per cent, because printers purchased special machinery to do special jobs, and when the jobs were finished the machinery was idle and might never be employed. W. Green emphasized the importance of standardization from the printers' point of view.

In his closing remarks Mr. Huson pointed out the importance of the printing industry and directed the attention of the engineering profession to its problems. He stated that the further development of this industry would challenge the skill and precision of the trained mind and indicated that the function of the Committee on Printing Machinery was to bring the engineering point of view to the assistance of the industry.

The paper on Size Standardization by Preferred Numbers, by Messrs. C. F. Hirshfeld[4] and C. H. Berry,[5] which appeared in the December issue of MECHANICAL ENGINEERING, brought out a very heavy discussion. The points developed therein require very careful editorial consideration and a more complete résumé of it will appear in a later issue of MECHANICAL ENGINEERING. Written discussions were submitted by C. G. Barth, Buckner Speed, F. O. Hoagland, L. D. Burlingame, L. B. Tuckerman, E. R. Hedrick, A. E. Kennelly, B. M. Eaton, E. H. Rigg, W. A. Durgin, W. A. DelMar, Major G. F. Jenks, C. J. Oxford, R. Trautschold, and E. Buckingham. Those orally discussing the paper were F. B. Gilbreth, A. L. DeLeeuw, W. H. Timly, and Alfred B. Carhart.

Safety Engineering

THE American Society of Safety Engineers joined with the Safety Codes Committee of the A.S.M.E. in the preparation of the program for the Session on Thursday morning, December 7, devoted to Safety Engineering. John W. Upp, Chairman of the Safety Codes Committee, presided, and the following papers were presented: Safety Codes, M. G. Lloyd; Safety Engineering in Connection with the Compression of Gases, A. D. Risteen; Safety Codes for Grinding Wheels, G. E. Sanford; and Some Hazards of the Logging Industry, John A. Dickinson. These papers will appear in abstract in a later issue of MECHANICAL ENGINEERING.

Ordnance Session

AT THE Session on Ordnance held Thursday afternoon, December 7, with Waldo H. Marshall, Chairman of the Ordnance Division, in the Chair, two papers recording wartime ordnance manufacturing experience were given. R. A. Vail[6] presented a paper on Methods Used in Manufacture of Gun Recoil Mechanism, and J. B. Rose[7] one on Machining and Lapping Very Deep Holes. An abstract of Major Rose's paper appeared in December MECHANICAL ENGINEERING. An abstract of Mr. Vail's paper with the discussion on both papers will appear in a later issue.

On Tuesday, December 5, members of the A.S.M.E. witnessed a demonstration of the Christie amphibious gun mount and as a special feature of this session, motion pictures of the demonstration were shown. In addition, the War Department displayed pictures of motorized artillery and modern types of guns.

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[3] Pres. Frank B. Gilbreth, Inc., Montclair, N. J. Mem. Am.Soc.M.E.

[4] Chairman, Research Dept. Detroit Edison Co., Detroit, Mich. Mem. Am.Soc.M.E.

[5] Engr. Detroit Edison Co., Detroit, Mich. Mem. Am.Soc.M.E.

[6] Assistant Production Engineer, Dodge Bros., Detroit, Mich. Mem. Am. Soc.M.E.

[7] Major, Ord. Div. U. S. A. War Dept. Fort Leavenworth, Kan. Mem. Am.Soc.M.E.

Aeronautic Session

PROF. E. P. Warner, Secretary of the Aeronautic Division, presided at the session on Aeronautics on Friday, December 7, at which the following papers were presented: Influence of Design on Cost of Operating Airplanes, Archibald Black;[1] The Airship for Long Haul Heavy Traffic Service, R. H. Upson;[2] and Air Navigation by R. W. Willson[3] and M. D. Hersey.[4] Mr. Black's paper appeared in the December issue of MECHANICAL ENGINEERING. Abstracts of the other papers and discussion upon them will appear in a later issue.

Forest Products Session

ON Thursday afternoon, December 7, Robert B. Wolf, Vice-President of the Society, presided at the Session on Forest Products. The following papers, which will appear in abstract in a subsequent issue of MECHANICAL ENGINEERING, were presented: New Factors Which Are Influencing Woodworking Machinery Design, S. Madsen;[5] Control of Lumber-Cutting Waste and Production, C. M. Bigelow;[6] Some Engineering Aspects of the Design of Musical Instruments, W. B. White;[7] Lumber Dry Kilns, Thomas D. Perry;[8] and Lumber Standardization, F. F. Murray.[9] Mr. Bigelow's paper is published in this issue and the other papers will appear in later issues.

Boiler Code Hearings

THE BOILER Code Committee held two hearings during the Annual Meeting. One on Monday morning, December 4, was devoted to the revision of the Code for Power Boilers. A number of groups entered into animated discussion of some of the features of the proposed Code. The safety-valve manufacturers discussed the limitation of the blowdown and multiplex casing; manufacturers of boilers for the oil country asked that the diameter of the dome be restricted to not less than 60 per cent; stamping was brought up by representatives of state and municipal inspectors; and there was also a discussion on the thickness of pipe walls. Although the Code for Unfired Pressure Vessels was not thrown open for discussion, there were a number present interested and they were given an opportunity to advance their views.

The hearing on Tuesday, December 5, on the Code for Low-Pressure Heating Boilers was taken up largely by protests against the requirement for preheating seams to be welded.

Hearing on Power Test Codes

AT THE Public Hearing on Monday, Dec. 4, the Test Code for Reciprocating Displacement Pumps and the one for Feedwater Heaters were discussed and a few changes suggested, after which it was recommended that the Council approve them for adoption as the recommended practice of the profession.

The First Power Exposition

THE first National Exposition of Power and Mechanical Engineering in New York City opened auspiciously on Thursday, December 7, and continued through December 13. Forty seven thousand five hundred and eighty visitors viewed the exhibits that filled one floor of the Grand Central Palace. The fact that this was the first show of its kind on a national scale makes it difficult to judge its value, but the comments of the visitors prove conclusively that a show of this character is needed and appreciated by those who are engaged in the design and operation of power plants. The Exposition was made up of over 100 exhibits and all classes of power plant apparatus and equipment, except large boilers and prime movers, were well represented.

[1] Consulting Engineer, Garden City, L. I. Mem. Am.Soc.M.E.

[2] Aircraft Development Corp., Detroit, Mich.

[3] Deceased.

[4] Physicist, U. S. Bureau of Mines, Pittsburgh, Pa. Mem. Am.Soc.M.E.

[5] M. E. Curtis Co., Clinton, Iowa. Mem. Am.Soc.M.E.

[6] Chief Engr. Cooley & Marvin Co., Boston, Mass. Mem. Am.Soc.M.E.

[7] Technical Editor, Music Trade Review, Chicago, Ill.

[8] Vice-Pres. and Secy. Grand Rapid Veneer Works, Grand Rapids, Mich. em. Am.Soc.M.E.

[9] Engr. Hardwood Mfgrs. Inst., Chicago, Ill. Jun. Mem. Am. Soc.M.E.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

More Information Service

THIS time it is an informational clearing house for the whole of science and engineering. The National Research Council in Washington is maintaining such a service as one of its major departments in order to promote research and to extend its usefulness to industry by increasing the availability of reliable information.

Mechanical engineers naturally will use the Engineering Library and the resources of their society to meet special and technical informational needs. But they are likely to find it distinctly worth while to use the Research Council Information Service as a source of help in the case of border-line subjects and such as lie entirely beyond the confines of mechanical engineering.

Research Information Service has a technical staff representing the chief divisions of science and technology. Members of this staff are constantly answering inquiries about research problems, methods, processes, apparatus, reports, and their relations to industrial progress. The Service specializes in sources. If it does not happen to have at hand the facts you need, it most likely can tell you where to find them.

Except as special search of the literature, compilation of a report, or copying of data make a charge necessary, the aid of Research Information Service is free. Mechanical engineers are cordially invited to use this new informational clearing house, not in place of the specialized service provided in the Engineering Research pages of MECHANICAL ENGINEERING, but in addition to it. The best possible way to find out about the usefulness of Research Information Service is to try it. The proper form of address is Information Service, National Research Council, Washington, D. C.

Research Résumé of the Month

A—RESEARCH RESULTS

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Air A3-22. A STUDY OF AIR-STEAM MIXTURES. This investigation was conducted by LeRoy A. Wilson, Research Associate in Mechanical Engineering, under the general direction of Dean C. R. Richards. It is the outgrowth of an investigation of the reheating of compressed air by Dean Richards, and J. N. Vedder, Research Assistant in Mechanical Engineering, the results of which have been published. In this earlier investigation the employment of steam as a reheating agent was found to result in an increased thermal efficiency for the mixture of air and steam, as compared with the use of either air or steam separately, in an engine operating expansively. The purpose in operating a reciprocating engine with a working medium composed of a mixture of air and steam was to determine the possible advantages in thermal efficiency resulting from the use of such mixtures having different proportions of the two components and with different initial temperatures of the compressed air.

The results of this experimental work have just been published as Bulletin No. 131 of University of Illinois, Engineering Experiment Station, Urbana, Ill. This bulletin treats the subject of air-steam mixtures in considerable detail, by both means of a theoretical discussion, and by reporting actual tests made with different proportions of air and steam at different initial air temperatures and under various load conditions. The thermal properties of various mixtures are presented in the form of Mollier charts which will greatly simplify the solution of problems connected with the subject. The bulletin contains 96 pages and its price is 75 cents per copy.

Steam Power A5-22. A STUDY OF AIR-STEAM MIXTURES. See *Air A3-22*.

Iron and Steel A6-22. THE PREPARATION AND PROPERTIES OF PURE IRON ALLOYS. Scientific Paper No. 453 of the Bureau of Standards, entitled The Preparation and Properties of Pure Iron Alloys, deals with fundamental principles involved in the manufacture of steel products. To protect life and property it is necessary that the architect and engineer know the kind of steel which should be specified for each use. To know what composition a steel should have in order to withstand a certain amount of strain or to meet necessary requirements, the effects on the steel of each of its constituents must be known. The general effects of each of these constituents have long been familiar, but technical difficulties have hindered really thorough studies of the specific and exact effects of each of the elements. Very pure iron is difficult to prepare, and it is even more difficult to add a controlled amount of some one constituent of steel to pure iron without some contamination.

In this investigation iron of practically 100 per cent purity was prepared by an electrical method similar to the method of silver plating in which the metal is deposited from a solution by the passage of an electric current. The iron is plated out, leaving the impurities behind. This iron was then melted in a vacuum to exclude the effects of gases which would be taken up from the air if melted in contact with it. The heating was done electrically, and the containing crucibles were made of chemically pure magnesium oxide.

This paper will be ready in a short time and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

Photography A2-22. PHOTOMICROGRAPHY OF PAPER FIBERS. This paper describes some of the more important factors in the photomicrography of vegetable fibers, especially those used in the paper industry. As regards illumination it is shown that the carbon arc can be advantageously replaced by an incandescent stereopticon lamp. Different types of objectives are discussed, and it is shown that the working qualities of most objectives may be greatly improved by the use of proper light filters, three types of which are discussed. It is shown that where an object lying in different planes is to be photographed, an objective of comparatively long focal length will give better results than one of shorter focal length, and that this arrangement requires a longer bellows extension. Different types of photographic plates are described and suggestions as to the best type of plate to use for photomicrographic work are given. Suggestions for staining and preparing the material to be photographed are included, as well as some regarding the value of photographs for permanent records and in the study and control of materials and mill processes. A short bibliography on photomicrography and related subjects is given.

This very timely paper, known as Bureau of Standards Technologic Paper No. 217, was prepared by R. E. Lofton, Associate Physicist at the Bureau of Standards. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 5 cents.

Wood Products A5-22. PHOTOMICROGRAPHY OF PAPER FIBERS. See *Photography A2-22*.

B—RESEARCH IN PROGRESS

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Corrosion B9-22. SOIL CORROSION OF IRON AND STEEL PIPE. The damage to buried pipe structures due to the corrosive action of soil is known to run into enormous sums annually. In order to throw further light on the ways and means of reducing losses from this source, the Bureau of Standards instituted, about a year ago, a very comprehensive investigation into the entire subject. This investigation has been undertaken first, to determine what types of soils throughout the country are especially corrosive to iron and steel; second, which kinds of iron and steel pipe are most resistant to the corrosive action of particular types of soils, and, third, the most practical means of reducing damage from this cause.

The work is carried on with active coöperation of the principal manufacturers of iron and steel pipe, the large public-utility corporations throughout the country as the principal users of pipe, and the Bureau of Soils of the Department of Agriculture. The steel and public-utility interests are incurring the major part of the expense of the investigation. The Bureau of Standards plans and directs the work. Approximately 9000 specimens of pipe have been furnished free of charge by pipe manufacturers.

Owing to the very urgent demand from many sources, it is planned to increase considerably the scope of this investigation. The brass manufacturers have requested that numerous brass specimens be included in the test, particularly of fixtures designed to be used with wrought-iron and cast-iron pipes. It is planned also to include a considerable number of specimens of pipe coated with various types of protective coatings. These will include some additional specimens of pitch-treated pipe, but will more particularly refer to metal-covered pipe, such as those covered by the various processes of galvanizing, also lead-covered pipe for which rather strong claims have recently been made. Arrangements have been made with the manufacturers of galvanized pipe and lead-covered pipe to furnish the necessary samples. These will be buried at the various locations when the first inspection of the iron pipes is made. Address Director of the Bureau of Standards, Washington, D. C.

Iron and Steel B9-22. SOIL CORROSION OF IRON AND STEEL PIPE. See *Corrosion B9-22.*

Radiation B1-22. EMISSIVITY OF COTTON CLOTH. Attention has been previously been called to an investigation which the Bureau of Standards is conducting to discover a roofing material which will keep the inside of a balloon hangar at a minimum temperature when exposed to the sun. It was shown that the most efficient means for reducing the heating of the interior of the building by solar radiations is by covering the outside of the roof with a highly reflecting substance, such as white paint or asbestos, and painting the inside of the roof with aluminum paint which is a poor radiator of the low-temperature long-wave-length radiation emitted by the roof.

During the past month a similar study has been made of white cotton cloth such as it used for tents. As is well known, when a tent is exposed to the sun the interior becomes uncomfortably warm from the sunlight which is diffusely transmitted through the cloth, and in particular as a result of the heat rays emitted by the cloth. By covering No. 10 duck on the inside with aluminum paint it was found that the heat radiation into the interior of the tent reduced 86 per cent. If the aluminum coating is on the outside the arrangement is less efficient, the radiation into the interior being reduced by only 78 per cent. While No. 4 duck would be too heavy for tents, it is interesting to note that by applying a coating of aluminum paint to the interior the heat radiation is reduced from 78 to 81 per cent. It is obvious that while such a tent would be more comfortable in the daytime, during the night the use of the coating of paint would act in the opposite way and retain the heat generated within, thus maintaining a higher temperature.

Welding B2-22. TEST OF WELDED RAIL JOINTS. An investigation is being conducted at the Bureau of Standards on the strength of rail joints in coöperation with the committee on welded rails, and six preliminary tests have been made of typical rail joints used on street railways. For this purpose the large horizontal Emery testing machine has been employed. Two specimens of thermit-welded joints, 1 riveted fishplate joint, and 1 standard 7-in. railroad rail section, as well as 2 specimens of electric butt-welded joints submitted by the Lorain Steel Company have been tested. The preliminary tests showed wide variations in the strength of the joints made by the different methods, but sufficient information was obtained concerning the method of test to determine the best means for gripping the specimens as well as the most satisfactory design therefore.

D—RESEARCH EQUIPMENT

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories.

Instruments and Apparatus D1-22. SPRAGUE DYNAMOMETERS. The Division of Engineering, Brown University, has recently installed in one of its laboratories two Sprague dynamometers each having a capacity oe 200 hp. These dynamometers may be used either separately or tof gether and are completely equipped with all the necessary auxiliary apparatus. With this apparatus power tests from 15 to 600 hp. may be made and the authorities of Brown University desire to make it known that these facilities are available. Those interested may address Prof. William H. Kenerson, Division of Engineering, Brown University, Providence, R. I.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Accuracy of Boiler Tests

TO THE EDITOR:

I have read with very great interest the correspondence under this heading, and I am afraid that fear of taking up too much space in your columns prevents me from joining in the discussion on all the very many different points that have been raised. I will content myself, therefore, with the question of the amount of steam or power used auxiliary to the production of steam.

A very serious defect in the revised A.S.M.E. Boiler Test Code, which applies still more forcibly to the British Institution of Civil Engineers' Code, is the scanty attention given to this question of steam or power used auxiliary to the production of steam. The simplest boiler plant, merely for the sake of illustration, can be taken as one boiler only, without any accessories, evaporating say, 5000 lb. of water per hour, and working with an injector, in which case the real steam output of the plant—apart from the infinitesimal amount of energy used by the injector—is 5000 lb. of steam per hour, and the real net working efficiency of the plant can be calculated on this evaporation. If now we use any appliance whatever auxiliary to the production of steam, which consumes steam to work it, then this amount of steam must be deducted in calculating the net working efficiency of the plant. If, for example, we install a steam-jet furnace taking 10 per cent of the production of the plant, that is, 500 lb. of steam per hour, then the real net working efficiency has to be calculated on an evaporation of 4500 lb. only, since this is the amount of useful steam that passes the stop valve into the factory. This sounds so elementary as to be hardly worth mentioning, but practically every boiler test that has been carried out in the world for the last century ignores this simple fact.

In my book, Boiler Plant Testing, I have given the exact detailed figures for the performance of 400 steam boiler plants in Great Britain, representing 1513 boilers in 41 different industries, and with a total coal bill of 3,250,000 tons per annum. In these boiler plants, which are thoroughly representative of British practice, and probably also, in fact, of steam generation throughout the world, a very large amount of auxiliary steam is used for coal conveyors, ash conveyors, mechanical stokers or mechanically moving bars, steam nozzles, mechanical forced or induced draft, boiler-feed pumps, water-softening plants, driving of economizer scrapers, in the electrolytic treatment of feedwater for the prevention of corrosion, soot cleaners, and for various other purposes, so that I should estimate that the amount of steam used in cylindrical boiler-plants under average good conditions can very easily reach $12^1/_2$ per cent of the production, and in the case of water-tube boilers $4^1/_2$ per cent. The worst example is that of the use of steam nozzles, and out of the 400 plants tested, 153—that is 38 per cent—were fitted with steam nozzles, the average amount of steam consumed by these being $6^1/_2$ per cent of the production, and varying from 0.5 per cent to no less than 21.5 per cent in individual plants.

It is of course absolutely necessary to deduct this auxiliary steam in calculating the real net working efficiency of the boiler plant, but the general lack of understanding on this point is seen by the fact that we have today firms making appliances for steam generation advertising broadcast figures of tests in which 75 to 80 per cent boiler efficiency is shown, while at the same time the fact that their own appliance may be wasting from $2^1/_2$ to 20 per cent of the steam production is coolly ignored.

The A.S.M.E. Revised Code only considers this matter of sufficient importance for a footnote, and merely states that such auxiliary steam ought to be determined and a record made if it has been included in the calculations or not. There is not the slightest indication given that this question of auxiliary steam is just as important as recording the amount of coal used and water evaporated, and that without such proper record, boiler testing is worthless. As I have stated in my book, the whole question of boiler-plant testing is a most complicated one, being a combination of technical chemistry and engineering quite outside ordinary practice, and it is high time, in my opinion, that we have an International Code devised which will put the matter upon a sound and practical basis.

DAVID BROWNLIE.

Manchester, England.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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Commercial Aviation in America

Howard E. Coffin

Any fair discussion of commercial aviation in our country today must of necessity consist largely of prophecies. For, to be frank, with certain notable exceptions there is little of commercial aviation worthy of consideration either as a transportation business or a production industry.

But we must not confuse frankness with pessimism. Just the same kind of statement might just as truly have been made twenty years ago with reference to the automobile business, and yet in these few years we have seen the motor-car industry achieve its present great place in the world's commercial affairs. What may not aviation, profiting by the experience of its automotive brother, be expected to do in a similar time? For here we have fulfilment of man's age-old dream, and here again the desires and needs of humanity are being served.

We are, in my own opinion, just upon the threshold of a remarkable expansion in the aeronautical-transportation art. Civilization, since the beginning of time, has never turned its back upon the newer, speedier, and more luxurious forms of locomotion and will not fail to grasp flying and develop it as an important adjunct to existing agencies of traffic and travel. The possibilities so far overshadow the problems that a successful commercial development of considerable magnitude seems beyond question.

A consideration of the many things to be done before we can expect aviation to become a dividend-paying agency in the commercial service is important. Listed in the order of pressing need they are:

First, control. An authoritative federal agency must be established by legislative action and charged with the regulation, encouragement, and control of air navigation. Federal inspection of all ships for airworthiness must be provided. All pilots and mechanics must be examined and licensed. A bureau for such work in the Department of Commerce is proposed in the Wadsworth-Hicks Bill now before Congress. The enactment of such legislation is essentially fundamental to any healthy growth of our aviation art.

Second, public confidence. Stunting at the county fairs, deviltries, and flights in poorly constructed and uninspected planes or by inexperienced pilots have occasioned far too many crashes. These accidents, emblazoned upon the front pages of our newspapers in the most sensational manner, have firmly instilled in the public mind the idea that all aviation is dangerous. Not until a convincing background of safe, sane flying history has been written in American air annals, covering a period of several years, will this fear be supplanted by confidence and faith. Time, energy, and skill expended in engineering achievement and in safeguarding air performance will slowly but surely overcome this handicap.

Third, governmental coöperation. Our nation, as a whole, is vitally concerned that commercial aviation shall progress rapidly. For such development constitutes an essential and fundamental basis upon which rest all plans for the future military-naval defense of our country. Perhaps the greatest single need of the moment is the adoption by our Government of a definite, comprehensive, and continuing program for the encouragement of our American aeronautical progress.

To illustrate, no direct subsidy is needed, but there is essential that same federal coöperation and assistance that is given our water-borne agencies of commerce. The Government has for many years indirectly subsidized shipping by the provision of ports, the charting of sea routes, the maintenance of bureaus for the disseminating of weather forecasts or meteorological data, the coast guard, the lighthouse service, and many other aids to water navigation. For our railroads there have been land grants and concessions, rights of condemnation, and elaborate federal bureaus governing labor and rates. The same kind of general aid must be extended aviation in the provision and maintenance of landing fields, wireless and radio signaling stations, beacon lighthouses for night flying, in scientific research, the charting of air routes, a code of air regulations, and in many other practical details.

Fourth, laws. Today the only law governing aviation in America is Newton's law of gravity. Forty countries have national air laws regulating the operation of civilian aircraft, designed specifically to encourage and regulate aviation as well as to eliminate flying accidents through reckless piloting or the operation of unsafe machines. Twenty-six nations have ratified the International Air Convention drawn in Paris in 1919. The United States of America is not among either class but is listed with Abyssinia, Persia, Bhutan, Nepal and Oman as countries which are not yet sufficiently forward-looking to enact legislation safeguarding life and property in air commerce.

The four needs enumerated are paramount. There are many other items in the catalog of aviation's requirements which can be met when time and experience permit. But, for the enthusiast of today, these four are immediately pressing and afford ample objective toward which our initiative and energy may be directed.

To aid in the settlement of these questions of commercial aviation, as well as to lend a hand in military and naval preparedness in the air, a new national body has recently come into being—the National Aeronautic Association. Born of the desire among thousands of our citizens for a channel of expression on aviation affairs, representative of every section of the country and of every element of our population, wholly without selfish ends, this association fills a well-recognized need and its formation marks one of the brightest spots in American aeronautic annals.

We have had for some time the Aeronautical Chamber of Commerce, representing the manufacturer and the operator; we have had the Society of Automotive Engineers, representing the designer and the inventor; and now we have that essential third member of the triangle, the National Aeronautic Association, representing the people themselves.

Thus, the picture is not empty of accomplishment. Even though we are in the infancy of commercial aviation, we have achievements to our credit of which we may well be proud. America holds all principal air records of the world: speed, endurance, altitude, long distance, all of which stand to the credit of American engineers, designers, pilots, and mechanics.

We have in the phenomenal performance of our transcontinental Air Mail the world's greatest application of commercial aviation. Every day except Sundays and holidays this service covers a round trip of 5360 miles, an annual flying schedule of 1,800,000 miles. From July 16, 1921 until September 7, 1922, this service flew ap-

proximately 2,000,000 miles without a fatal accident. During the fiscal year ending June 30, 1922, an efficiency of 94.39 per cent was maintained. That is, during that year out of every 100 trips scheduled, 94.39 were finished on schedule time. And remember that this route crosses three mountain ranges, the Alleghanies, the Rockies, and the Sierras.

Of almost equal importance has been the record of the Aeromarine Airways Company, specializing in passenger transportation. During the past three years this company has flown more than 1,000,000 miles, carrying more than 15,000 passengers and without a single mishap. It is only by an actual showing or promises performed that the public confidence can be gained and retained, and the wonderful records being made by the Air Mail Service and the few commercial companies operating are doing much toward this end.

We may well be optimistic. For, with all these records of achievment to the credit of our air industry, and with a strong national patriotic body dedicated to the furtherance of this new transportation art, it lies easily within our hands to put "America First" among the world's air powers.

Let's do it.

HOWARD E. COFFIN.[1]

The A.S.M.E. Annual Meeting and the Power Exposition

THE holding of the first National Exposition of Power and Mechanical Engineering following the recent Annual Meeting of The American Society of Mechanical Engineers resulted in an instructive combination that should do much to inspire the members of the A.S.M.E. The meeting with its broad, diversified program and well-balanced sessions established a new precedent, and its supplement this year with a technical exhibit added an element of appeal that will be strengthened as the scope of the Exposition grows.

The Committee on Meetings and Program is somewhat concerned about the intensity of the past meeting with its twenty-four professional meetings, four entertainments and several excursions and industrial visits. Under the present conditions of great activity and diversity of members' interest it cannot be relieved, and the Committee must rely on its ability to arrange a program with the least amount of conflict between sessions with related papers. The problem will grow more severe as the Professional Divisions of the Society increase in activity. However, wealth of material for meeting programs is an embarrassment to be welcomed and one that can be overcome by the provision of more meetings or the diversion of material to regional meetings.

Notwithstanding the intensity of the Annual Meeting program, members have asked that the Power Exposition be arranged to parallel the meeting rather than follow it so that those from a distance may have more time to attend the meeting sessions they desire and also to spend the necessary amount of time at the Exposition. The Committee on Meetings and Program is giving consideration to this arrangement which is desirable and seems practical. The increase over last year in the number of out-of-town members who registered at the meeting this year is one reason why careful thought should be directed to the parallel plan.

The announcement that the Power Exposition will be continued next year will be greeted with pleasure by those who visited the Grand Central Palace this year and enjoyed the collection of latest devices, the mass of instructive data, the complete program of interesting educational moving pictures and the remarkable opportunity for broadening acquaintances. Although some important classes of power-plant equipment were not thoroughly represented, and it is hoped this omission will be corrected as the Exposition becomes established; the general character of the exhibits was excellent and every one who visited the Show carried away some ideas.

One important function of the Exposition must not be neglected. It is visited by many individuals who may not be informed about the problems of generating, distributing, and using power. In fact only a small percentage of people do understand the variety and severity of the engineering phases of the power problem. As Dean Kimball pointed out in his presidential address, the engineer has a grave responsibility in maintaining civilization. A more general appreciation will assist the engineer in shouldering this responsibility, and an exhibit such as this will assist greatly in extending general knowledge if the coöperation of the exhibitors is secured.

[1] President, National Aeronautic Association.

Improvements in The Engineering Index

THE Committee on Publication and Papers takes great pleasure in announcing two changes in The Engineering Index which it is hoped will greatly increase its service value to the readers of MECHANICAL ENGINEERING. One of these is the placing of the Index items on one side of the sheet only so that items may be clipped, and the second is the addition of one page of items from technical journals received up to three days before going to press.

The Committee has been encouraged in making these changes by the increased demands on the Library for information, especially about articles from the current technical press. These requests come not only from research organizations but from individuals who are anxious to broaden their knowledge and who rely on The Engineering Index as their guide to the many excellent publications in the engineering field. This increased demand is also an encouraging symptom, indicating that the engineering public is becoming appreciative of the sources of recorded experience. For a long time we have felt that engineering libraries were not appreciated or used as widely as they should be by engineers, but the increase in use of the Index is an encouraging indication.

Perhaps a word should be said in explanation of the page of late items. The operation of setting the main portion of the monthly Engineering Index in type is laborious and requires painstaking proof reading. It is desirable to get this completed before the remainder of the text pages is ready and the Index is therefore closed a considerable time before the date of mailing. The inclusion of late items on a separate page will thus bring the Index more nearly up to date.

The Engineering Index must of necessity be selective, as the inclusion of all articles in all technical publications is obviously impossible. The annual volume of The Engineering Index includes all items that have been indexed from the publications that come to the Engineering Societies Library, but MECHANICAL ENGINEERING contains only those of particular interest to mechanical engineers.

Engineers from Egypt and Czechoslovakia Study American Methods

ILLUSTRATIVE of the growing recognition of the internationality of engineering is the mission of ten graduates of the engineering schools of Egypt who have been sent to America by the Egyptian Government to study manufacturing methods in this country. Their expenses during the two years that they will remain here will be paid by the Egyptian Government. They have been placed in various factories by the Department of Commerce and will work as employees while they are acquiring a knowledge of American methods and machine-shop equipment. Subjects which will be studied by them are interchangeable manufacturing, railroad transportation, telephone systems, marine engineering, and internal-combustion-engine construction.

A young Czechoslovakian engineer is in this country on a similar mission in regard to the building trades. Through the aid of the Czechoslovakian Minister and the General Contractors' Association he will be enabled to obtain a thorough acquaintance with methods, equipment, and material used in construction in this country.

Undoubtedly these young engineers will have great influence upon the industries of their native countries in the near future. It is to be expected also that the introduction of American methods will increase the demand for American tools and equipment. But farther reaching still are the benefits accruing both to them and to us by the personal contacts thus established between members of the profession in those countries and in the United States.

The Monroe Palace—Administration Building of the

Brazilian Centennial Exposition, Opened in September, 1922

Calvin W. Rice Reports on South American Trip

Envoy to International Engineering Congress in Brazil Visited Eight Pan-American Countries—Standardization Work Pledged by Resident U. S. Engineers

YOUR Secretary sailed from New York for Rio de Janeiro on August 24 on the S. S. *Pan America*, the United States Shipping Board boat which carried the Secretary of State, Mr. Hughes, and his party to the Brazilian Centennial Exposition. I sailed as the official representative of The American Society of Mechanical Engineers and the other principal engineering societies of the United States and Canada, to the International Engineering Congress at Rio de Janeiro scheduled for September 17 to 30, and as the representative to the Brazilian Centennial Exposition of several civic bodies and of President D'Olier of the Sesquicentennial Exposition Association of Philadelphia of 1926.

When advised of my appointment, I saw an opportunity to link up membership on one of the sub-committees of the Inter-American High Commission with my relationship to the Engineering Congress and possible visits to associations of engineers in the several South American countries. Convinced of the beneficial results that might arise from such contacts, Herbert Hoover and Dr. L. S. Rowe, respectively president and secretary-general of the Commission, gave me letters to the corresponding officials of the Section of the Commission in all the South American countries I was to visit. Inasmuch as standardization of product in each country will promote the welfare of that country from both an industrial and commercial viewpoint, Mr. Hoover wrote me that—

> If his Excellency, the Minister of Finance,[1] finds it possible to hold a meeting of his Section of the Inter-American High Commission, I trust that it will be possible for you to discuss with some of the members the problem of standardization.

At that time, in all of South and Central America there was no such thing as a standardization committee or bureau. The need for work in this direction had long been apparent. This gave me a practical message to take to associations of both native engineers and members of United States and Canadian Societies in the countries I was to visit, for they, with their special training, could render a great service in such a work to the countries of their adoption.

With this in mind I purposely booked passage on the *Pan America*, for, knowing Secretary Hughes' personal admiration for Mr. Hoover, I wished to obtain, if possible, the official interest and support of the Secretary of State for Mr. Hoover's message. In several interviews on board ship I found Mr. Hughes enthusiastic over this particular activity of the Inter-American High Commission. He gave most helpful advice as to the method of presentation. He further gave his support in every way, and when I later presented my program to officials and engineering organizations I was able to say freely that it had the whole-hearted approval of our Secretary of State.

The high place which the engineer holds in South American affairs is indicated by the fact that outside of the government, the Club de Engenharia of Rio de Janeiro was the only organization that presented Secretary Hughes with an address during his first visit to Brazil. Mr. Hughes' recognition of the high place the engineer is to hold in world development is seen in his epoch-making address delivered at the dedication of the site of the monument which the United States is to give to Brazil. He said:

> The resources of science are marshaled under efficient direction to meet the peculiar increasing needs of civic life. . . . . But this fortunate land of Brazil is one of constant revelations and today more than ever before we are appreciating the limitless possibilities of its development, of the prosperity the future has in store for its people, and the extraordinary promise of their service to humanity. . . . . The various organizations now gathering here remind us that science has no frontiers. . . . . . . We have also gathered here the engineers for whose precise knowledge and trained hands Nature has long been waiting.

I arrived at Rio de Janeiro on September 5. The two weeks between that date and the opening of the Congress were spent by United States engineers in Rio in daily meetings to coöperate with the Club de Engenharia under whose auspices the Congress was being held. Our meetings, while not official in character, were a

[1] In every country but ours, the Minister of Finance is Ex-Officio Chairman of the Inter-American High Commission of his country. This work in the United States was transferred from the Treasury Department to the Department of Commerce after Mr. Hoover became Secretary of the Department of Commerce.

great aid in preparing for the Congress. Most of the papers that made up the program, lantern slides, and several motion-picture films on industrial matters were coming from the United States, and much patient and discouraging work was done in getting everything through the red tape at customs and ready for the meetings.

At a formal afternoon reception the Board of Management of the Club de Engenharia received my credentials together with those of Verne L. Havens, Editor of *Ingenieria Internacional* and delegate of the American Society of Civil Engineers. At another reception credentials were received from A. W. K. Billings, F. H. Shepard, and Dr. T. T. Read, representing civil, electrical and mining engineers.

The Congress itself was formally opened on Sunday evening, September 17. Dr. Pires do Rio, Honorary President of the Congress, who made the opening address, is Minister of Public Works and one of the most influential men of Brazil. He said in part:

> The word "engineer," builder of engines or machinery, as defined by the dictionaries, has actually a large significance in view of the magnificent industrial movement caused by the invention of the steam engine and its application to the industries of transportation and manufacture. . . . . The new industrial civilization, characterized by the use of the steam engine as a prime mover, and steel machinery as the instrument of operation, crowded the years of the last century with such a procession of important events that all that has gone before the Watt steam engine appears to be of but petty importance. . . . . . . The engineering profession responded to the call of this new state of industrial activity, and engineers ceased to be merely military officers, entrusted with the management of the crude machinery of warfare. They have become men of high technical education, accustomed to directing the work of exploitation of mines for the recovery of minerals, to designing and constructing blast furnaces, building railroads, laying pipe lines which supply cities with water and protect them from floods, and finally, to designing and building electrical machinery in all its modifications of shape and construction.

The address of Dr. do Rio was one of the high spots of the Congress. A brilliant banquet at the Jockey Club was given later in his honor and that of the officers of both the Congress and the Club de Engenharia, by engineers from the United States. It was an occasion which cemented the friendship of the engineers of the two continents.

Sessions of the Congress continued through October. The South American Railway Congress was scheduled to meet at the same time and place, and in order to avoid conflict the International Congress postponed some of its sessions so that it did not close on September 30 as had originally been planned. The attendance was not large. It consisted mainly of local engineers with a few from Chile, Argentine, and Peru. There were eight sections holding meetings. Four of these had for their presidents engineers from the United States. A fifth section had a United States engineer for its secretary. The sections and their presidents were:

1 Overland, Maritime, Fluvial and Aerial Transportation. The Pan-American Railway. Practical Means for Its Construction. (*President*, Dr. Santiago Vicuna)

2 Iron Metallurgy. (*President*, Col. C. H. Crawford)

3 Fuels. (*President*, Dr. Heitor Escardo)

4 Hydraulic Power, Its Utilization as Motive Power. (*President*, A. W. K. Billings)

5 Sanitation, Dams, and Irrigation. (*President*, Dr. Francisco Saturnino de Brito)

6 Maritime and Fluvial Ports. (*President*, Calvin W. Rice)

7 Machinery for Agricultural and Industrial Purposes. (*President*, Dr. Barbosa Goncelves)

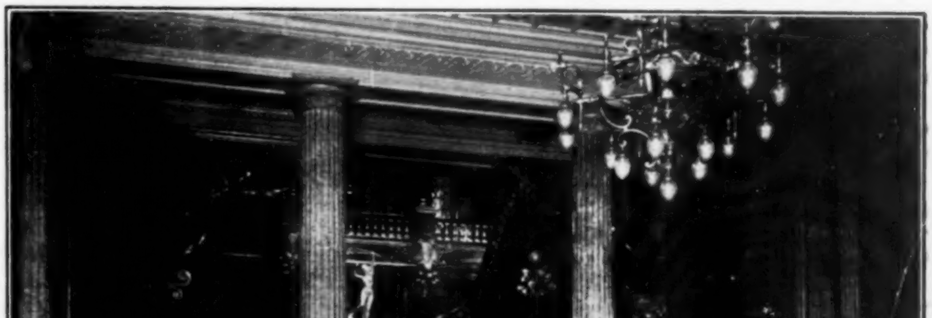
8 Standardizing of Statistical Methods in Ports and Railways. (*President*, Verne L. Havens)

The actual accomplishments of the Congress are shown in three resolutions which were passed. The first was one to effect a permanent organization to carry out the resolutions of the Congress. The second recommended legislation in every Pan-American country to establish a standardization bureau as suggested by Mr. Hoover. The third was a resolution to call a meeting of the nations to develop the dream of the Transcontinental Railway. Minor C. Keith, of Costa Rica, the only living member of the committee which originally recommended the building of this railway, has been asked to call this meeting to order.

A specific piece of standardization work has already been undertaken by a group of United States engineers in South America who have pledged themselves to develop a list of all technical words and phrases used in Portuguese. As neither Spain nor Portugal has ever developed a technical vocabulary, technical words and phrases often have different meanings in different localities. Mr. Havens, as a representative of the McGraw-Hill Publishing Co., promised to publish this commendable work when it is completed. It is quite possible that a similar vocabulary of Spanish words and phrases will be compiled later.

As to the Exposition, I attended the opening session as the representative of civic bodies and of President D'Olier. However, the Exposition was not in readiness and had been postponed until December. As a personal representative of Mr. D'Olier and of the Societies, including the Engineers' Club, of Philadelphia, I gave a formal invitation to South American engineers to attend and participate in the International Engineering Congress to be held in Philadelphia in 1926. I was a guest at several receptions in connection with the Centennial Exposition, and certain others given in Mr. Hughes' honor. No one knows better how to entertain than our South American neighbors. The two largest receptions I attended, one given by the President of Brazil in the Catette Palace and the other given in the Itamaraty Palace by the Minister of Foreign Affairs, excelled in setting and magnificence anything ever given in the United States and remind one of the court functions of Europe.

I left Brazil on September 28, and between that time and my return to the United States on November 13, I visited Uruguay, Argentina, Chile, Peru, Panama, Costa Rica, and Cuba. In each country I had a uniform method of approach. I called first at the American Legation. The next step was to call upon the president of the local engineering society, and with him I then called upon the members of the Inter-American High Commission with



INTERIOR VIEW OF THE JOCKEY CLUB OF BUENOS AIRES

my letters from Mr. Hoover and Dr. Rowe. In each country I urged—

1 That every professional man from the United States affiliate with the local engineering society of the country where he is residing, even if only temporarily;

2 That they form within or under the auspices of the local society groups of members of the National Engineering Societies of the United States for purposes of service to the local society;

3 That the local society link up with its government;

4 That the organization of engineers—members of U. S. Societies—link up—

a With their country's government through the embassy and commercial attaché and with the Inter-American High Commission;

b With the National Engineering Societies of the United States.

This, briefly, is the program suggested, and in several countries I was able to bring engineering organizations together with their governments for the first time. But in one country at least they are ahead of us in such matters: I refer to Cuba. If you will examine the census of Cuba for 1919 you will find that the National Board of the Census consists of three members, one chosen by the Civil Division of the Supreme Court, one by the Council of the University of Havana, and the third, an engineer chosen by the general council of the Cuban Society of Engineers. Furthermore, a law was passed in Cuba in October last providing for a commission of three to investigate Cuba's outstanding indebtedness, and this commission is to be similarly chosen: one by the Supreme Court, one by the Minister of Finance, and the third an engineer chosen by the Cuban Society of Engineers. Such participation in national affairs is an ideal toward which we may all strive.

In all the Pan-American countries I was impressed by the high regard with which the people hold those in the engineering profession. In all South America they are addressed as "Doctor" and are correspondingly respected. A man aspiring to a public career finds that an engineering education and training best fits one for political positions of responsibility and honor. Further, a South American is a world citizen with a keen grasp on international affairs. The newspapers of South America devote much space —especially preferred-position space—to international news and discussions, and murders and divorces are relegated to unimportant positions if published at all.

Without a single exception in my three months' travel of 15,000 miles everything was characterized by infinite patience and courtesy. So marked are these traits that it is essential that our official and commercial representatives to these countries have these qualifications and instincts. The ideals of our people are not truly represented if our representatives lack these qualifications.

The work of furthering international good feeling between our nation and the Pan-American countries will have the aggressive support of the South American engineer. The results of the International Engineering Congress are a foundation on which effective, permanent work may be built. Nothing less than a program devoted to the public good will form a basis for future work acceptable to the ideals of the engineers of the two continents.

Calvin W. Rice, *Secretary,*
The American Society of Mechanical Engineers

Engineer Heads Italian Embassy

Prince Gelasio Caetani, an engineer of international reputation and a member of one of the oldest families of Europe, has been appointed Italian Ambassador at Washington. He succeeds Senator Ricci who resigned when the Fascisti came into power.

The new Ambassador is a graduate of the School of Mines of Columbia University, class of 1903. Following his graduation he went West where he worked his way in true American fashion as miner, trammer, timberman and millhand. He later opened offices in San Francisco as a consulting engineer and became a member of the firm of Burch, Caetani and Hershey. The World War found Caetani still in this country but he returned to Italy immediately and became a Captain in the Engineer Corps.

The War record of Prince Gelasio is an enviable one. He was advanced to the rank of Colonel and three times decorated for bravery. It was Caetani who laid the mine that, with a single blast, blew up the whole top of the Col di Lana which destroyed an Austrian fort and opened the way for the Italian Army through the Cordevole Pass in the Upper Trentino. This feat was made possible by the practical experience which he had acquired in engineering studies in the United States. To accomplish it he designed a gallery under the fort nearly 2000 feet long.

After the war Prince Gelasio returned to the vast estates of the Caetani family near Rome where he combined a life of politics and business. He was one of the first of the Roman aristocracy to enter the political fight against socialism and communism. He became actively affiliated with the Nationalist Party when it was decidedly the unusual and unpopular thing for a man of his rank to do so. In December, 1920, Prince Gelasio enrolled himself among the original ninety Fascisti organized as a Roman cohort. At the last electoral campaign he was chosen a Deputy on the Nationalist ticket. He now comes to Washington as the first representative of the Mussolini Government there.

Underwood & Underwood
Prince Gelasio Caetani

The choice of Prince Gelasio Caetani to this important post is indeed a happy one. He is a true representative of the Italian people. The finest of Roman blood and traditions belong to him by inheritance; the right to represent Italy he has earned by personal service to her. For a thousand years the Caetani family has been closely identified with the history of the Eternal City. It has given several Popes and a number of Cardinals to the Holy See. The grandfather of Prince Gelasio, the thirteenth Duke of Sermoneta was a bitter enemy of the church and took an active part in bringing about the fall of the temporal power of Pope Pius IX.

Caetani himself has devoted his efforts since leaving the army to the stabilization of his war-stricken country in its dangerous period of reconstruction. Unemployment became a terrific problem. Communistic ideas took root and grew rapidly. For at least six centuries the Caetani family had owned a large part of the Pontine Marshes, celebrated in literature by Pliny the Younger. The land was unproductive. A low-lying lake with no outlet had over-flowed for centuries making marsh land that was of no commercial value. Returning from military life, Prince Gelasio planned and soon began the construction of a canal leading from Lake Caprolace to the Mediterranean. This mammoth undertaking, completed in 1920, reclaimed hundreds of acres of land for Italy. It was a big step in the solution of Italy's food and unemployment problems.

Although Ceatani is but in his forty-sixth year his wide experiences admirably fit him for the important post for which he has been chosen. He considers America his second home and his many friends here, who think of him just as "Gelasio Caetani," know that he is a personage as well as a Prince, a man who comes to Washington with a trained scientific mind and an understanding of the two countries whose immediate future relations lie largely in his hands.

Caetani is a member of the American Institute of Mining and Metallurgical Engineers. His friends in the National Engineering Societies are planning a dinner in his honor after his arrival in this country and the presentation of his credentials in Washington.

News of The Federated American Engineering Societies

National Board of Jurisdictional Awards

SPEAKING at a session of the A.S.M.E. Annual Meeting on December 6, L. W. Wallace, secretary of the F.A.E.S. characterized the activities of the National Board of Jurisdictional Awards as one of the most important and far-reaching pieces of work in which the Federation is engaged. Rudolph P. Miller, who is the representative of American Engineering Council on this Board, later addressed the membership on the organization, the activities, and the value to the nation of the Board. His chief purpose was to acquaint the engineers present with the salient facts concerning the organization, for despite the fact that it has been in existence since March, 1919, and has arbitrated a large number of jurisdictional strikes, comparatively few of the engineering profession appreciate or are even aware of its great influence on the building industry. Mr. Miller's address, together with supplementary details, is presented in the following paragraphs.

Practically since building-trades unions have been organized there have been from time to time disputes as to which group of mechanics should do certain work in connection with building construction. The development of asphalt shingles or strip shingles for roofing purposes, for instance, has been the cause of dispute as to whether such shingles shall be placed by the carpenter, whose jurisdiction over wooden shingles has never been questioned, or by the roofer, who has jurisdiction over other forms of roofing. Such disputes lead to strikes on building operations and the losses incidental to them fall directly on the mechanics and contractors, indirectly on the owner who must foot these bills, and ultimately on the general public.

The waste in industry due to such jurisdictional strikes has been estimated to run into millions of dollars. E. J. Russell, vice-president of the American Institute of Architects, and chairman of the Board, estimates that previous to the establishment of the Jurisdictional Board the cost of building operations was increased from seven to eight per cent unnecessarily because of jurisdictional strikes.

These considerations prompted the calling of conferences, about four years ago, of representatives from the American Institute of Architects, Engineering Council, the Building Trades Department of the American Federation of Labor, the Associated General Contractors of America, the National Building Trades Employers' Association, and the National Association of Builders' Exchanges. The purpose of these conferences was to organize a board to which jurisdiction in the building industry might be referred. It was a momentous step that was taken when these participating organizations voluntarily agreed to organize such a body and to accept and abide by its decisions.

The Board as now organized consists of eight members, one representative of the American Institute of Architects, one of the F.A.E.S., three representatives of the contractors' organizations, and three of the Building Trades Department of the A. F. of L. It is felt that such an organization is fairly representative of the building industry at large for the purpose of settling jurisdictional disputes.

Mr. Russell, who is an architect of St.Louis and the representative of the American Institute of Architects, has been the chairman of the Board ever since its formal organization in August, 1919. William J. Spencer, secretary of the Building Trades Department, A. F. of L., has been its secretary.

Complaints with regard to jurisdiction to be considered by the Board must be submitted in writing through the officials of one of the organizations that are parties to the agreement. A brief statement with regard to the complaint is forwarded to those who are immediately interested in the matter, and a time is set for the hearing of the case. Not only are the unions immediately affected given an opportunity each to present its claims and arguments, but frequently manufacturers and contractors who have an interest in the controversy are invited to present facts and evidence that they may wish to submit. For instance, in the dispute between the elevator constructors and the electrical workers over electrical work on elevators, the elevator manufacturers were given an opportunity to present their views. In that case the Board, in its endeavor to master the situation fully, went so far as to invite an elevator expert who had no interest in the dispute to give testimony on the technical questions involved.

Cases have also arisen where the manufacturers in offering a new material in building construction found difficulty in marketing their product because the mechanics of different unions claimed jurisdiction over the placing of that material, and architects hesitated to specify it for fear of starting a strike on the building. Such a case was that of Bestwall plaster board, in which case the matter was brought to the attention of the Jurisdictional Board through American Engineering Council.

A two-thirds vote of those members entitled to vote is required to render an award in all cases. That means ordinarily six votes are required. But according to the constitution, a member of the Board is not entitled to vote or to participate in discussion in executive session when the decision is fixed if he is immediately interested in the result of the controversy. In such cases provision is made for the appointment of an umpire whose decision shall be final.

Since its organization the Board has had about four meetings a year. It has rendered thirty-eight decisions, including fourteen confirmations of agreements that had been entered into some time previous to being presented to the Board, or that were the result of a suggestion in the course of a hearing. Generally a controversy was between two unions, but in six cases, three unions appeared as claimants for the same work, and in one instance four unions were involved in the dispute. Of the seventeen unions that constituted the Building Trades Department when the Jurisdictional Board was first established, thirteen have appeared as claimants before the Board.

Mr. Miller enumerated these unions, which include plumbers and steam fitters, iron workers, wood, wire and metal lathers, bricklayers and plasterers, painters, electrical workers, carpenters, roofers, sheet-metal workers, and elevator constructors, and stated that the decisions of the Board have been well observed and supported in practically all cases. The work of the Board was highly commended at the Cincinnati convention of the American Federation of Labor, in June, 1922, and at a recent meeting of the Executive Council of the A. F. of L. a resolution was passed condemning the jurisdictional strike and threatening drastic action against such unions as refused to join in any movement to avoid such strikes.

Mr. Miller felt that engineers and architects in many cases failed to support the work of the Board through lack of knowledge of its existence. What they are more especially asked to do in support of this movement was expressed in the resolution of the Board at a meeting in March, 1922, as follows:

Resolved, That the members in the American Institute of architects and The Federated American Engineering Societies insert in all specifications and contracts for building operations a stipulation that the decisions of the Jurisdictional Board shall be observed.

Mr. Miller cited a number of cases in which the decisions of arbitrary bodies have been upheld by the courts and stated that he believes that such decisions indicate that the courts would heartily support any movement, such as the work of the Jurisdictional Board, that would tend to eliminate dispute and trouble.

Referring again to the extra expense of building operations because of jurisdictional strikes, Mr. Miller stated that while it is practically impossible to get definite figures, an estimate made by Mr. Russell places the present cost at about-one-half of one per cent of the total.

Topographical Mapping

AMONG the important questions which will be discussed at the annual meeting of the American Engineering Council to be held at the Cosmos Club, Washington, D. C., January 11 and 12, is that of topographic mapping. Secretary Wallace, at the Business Meeting of the A.S.M.E., said that topographic maps of only about 34 per cent of the area of the United States have been completed. At the present rate of progress it will take from 80 to 100 years to complete the topographical survey of the country and the production of the necessary maps.

Realizing the pressing need for such maps, the Federation will give its active support toward the passage of the Temple Bill which provides a plan whereby the work may be completed in from 20 to 25 years. Efforts will be made to have this bill brought up for hearing in the near future. Meanwhile the state administrative committees of the F.A.E.S. are coöperating with the state geologists throughout the country in an educational campaign on this subject. Information is being assembled as to the progress of topographical work in the various states and existing and proposed legislation thereon so that senators and congressmen may know the respective requirements of their states.

The necessity for such maps is said to be just as pressing in the East as in the South and West. They are essential to highway and railway construction, to the location of barge canals, feeders and reservoirs, to flood control, hydroelectric development, and to land drainage, which latter affects not only the productivity of the land but also, through problems of municipal water supply and sewage disposal, the health of the nation.

Government reorganization, the Muscle Shoals investigation, letting of Government contracts, flood control, elimination of waste, and the 12-hr. shift in industry, together with other matters which have been part of the F.A.E.S. program during the past year, will be reported upon at the Annual Meeting.

Engineering and Industrial Standardization

Code for Identification of Piping Systems

IDENTIFICATION of fluids carried by pipes has in the past engaged the attention of many managers of industrial plants and superintendents of power stations. Five systems of color identification were published in the July, 1921, issue of MECHANICAL ENGINEERING. One of these systems had been developed by a Special Committee of The American Society of Mechanical Engineers.

We can now report that the Sectional Committee there announced has completed its organization with twenty-six members who represent twenty-four organizations. A. S. Hebble, the representative of the Society of Naval Architects and Marine Engineers, was elected chairman of the Sectional Committee at its first meeting held June 14, 1922, and I. G. Hoagland, the representative of the National Automatic Sprinkler Association, was elected secretary. The principal business of the organization meeting after the election of officers was the appointment of the Plan and Scope Committee.

This Committee was headed by W. S. Morrison as chairman and consisted of E. J. Cole, Crosby Field, W. J. Venning, H. P. Weaver, W. S. Morrison, A. S. Hebble, and I. G. Hoagland. It held a series of meetings during the summer and early fall and on November 10 presented a very carefully prepared report to the Sectional Committee. After a very thorough discussion the report on Plan and Scope was unanimously adopted with a very few minor changes. An abstract of this report is given below.

PART I

General Limitations of Plan and Scope

The plan and scope of the Sectional Committee on Code for Identification of Piping Systems shall be confined to the code of identification of piping systems in industrial and power plants, not including pipes buried in the ground

Definitions

Piping systems for the purpose of this code, in addition to pipes of any kind, shall include fittings, valves, and pipe coverings. Note that there shall be specifically excluded therefrom supports, brackets, or other accessories. Note also that the definition of pipes shall be hollow conduits for the transport of gases, liquids, semi-liquids or plastics, but does not include solids, as pipes carrying solids are more properly believed to come under the general classification of conveyors. Note also, that electric conduits are specifically excluded.

By "power plant" is meant any plant producing any of the following substances: steam, gas for heating or lighting purposes, electricity, compressed air, vacuum, water pumping, refrigeration and ice, air conditioning; but specifically not plants for the production of various chemicals or in which operations are performed for other purposes than the transfer of units of heat from one form into another more readily usable form. Note that "power plants" specifically includes heating plants.

Identification

It is obvious that to attempt to outline a code in which every product liable to be transported would have its identification, would result in a system so comprehensive that even should the supply of colors and identification symbols hold out, adoption of it would be automatically rendered impossible in those industries which do not have a major group of colors allocated to its products. It is found, however, upon investigation, that any materials transported in pipes in a plant fall in one of the following classifications:

(a) *Safe Products.* This represents a majority of the products that are handled through a plant. These products may be defined as having no hazard in their handling and no extraordinarily high value, so that a workman in approaching a piping system to make repairs will run no undue hazard in breaking into a pipe bearing a safe material, even though that material had not been emptied by previous arrangement.

(b) *Extra Valuable Material.* This might be classified as a part of the safe materials above mentioned, but inasmuch as cases came to your committee's attention where those products would have a very high value, it appeared preferable to give them a separate major classification.

(c) *Dangerous Materials.* These materials are those which inherently in themselves are hazardous to life or property by virtue of being easily flammable or productive of poisonous gases or are in themselves poisonous. They include of course materials that are known ordinarily as fire producers and explosives.

(d) *Protective Materials.* Under this class fall materials which are piped through plants for the express purposes of being available to prevent or minimize the hazard of the dangerous materials above mentioned. Thus, a plant may have certain special gases which are antidotes to poison fumes, which gases are piped through their plants for the express purpose of opening or breaking the pipe in cases of danger.

(e) *Fire-Control Equipment.* This might properly be called a division of the Protective Materials just mentioned above, though the hazard of fire and the use of sprinkler systems and other fire-fighting equipment having become so universal, it would appear better to make it a special major classification.

These five classifications, or subdivisions thereof, if necessary, in the opinion of your committee should be each given a major color, and the various subdivisions that a plant may need can be obtained by the use of numbers, names, or the like, painted in white or black upon the background of the color selected.

Machinery for Further Work

It is suggested that this work be carried on by four committees, having not over five members each, appointed by the chairman, and having the following duties:

(a) *Executive Committee.* It is felt that the size of the entire committee is so great as to render it very difficult to transact any work other than that of approving and modifying codes presented to it. It is therefore suggested that an Executive Committee be appointed to act for the Main Committee subject to its approval, and to receive the reports of the other Sub-Committees. It is recommended that the personnel of this Committee consist of the Chairman and Secretary of the Main Committee and the Chairman of each of the three Sub-Committees mentioned immediately hereinafter.

(b) *Sub-Committee on Identification by Colors.* It is felt that there should also be a sub-committee whose function it shall be to present to the Executive Committee suggestions for various colors and confirmatory evidence that those colors can be used universally. It must be here interjected that some of the members having had the largest experience in this matter have found it almost impossible to use paints when subjected to various fumes, etc. The selection of the basic colors, therefore, should be those that are most nearly resistant to the ordinary acids met with in commercial practice. It shall also be the duty of this Sub-Committee on Paints to prepare specifications for the paints selected.

(c) *Sub-Committee on Classification.* It is obvious that there are a great variety of requirements in the large number of industries to be represented and yet unless practically all industries are included prior to the issuance of the code it becomes extremely likely that certain industries will find their needs have been overlooked. It is therefore suggested that a Sub-Committee on Classification be appointed, whose function it shall be to communicate with representatives of the various industries, obtaining from each industry a list of the materials piped through their plants, classified according to the classification given under paragraph five of this report. It shall also be the duty of this Sub-Committee to combine the data received from the various industries, placing all the materials under one of the five major classifications. When these data have all been compiled, the Sub-Committee on Classification shall meet jointly with the Sub-Committee on Identification Markings Other Than Color hereinafter mentioned, for the purpose of assigning the markings selected by that Committee to the various materials under the five major classifications as compiled by this committee.

(d) *Sub-Committee on Identification Markings Other Than Color.* It is also felt that a Sub-Committee on Identification Markings Other Than Color should be appointed, whose duty it shall be to investigate the various form and shape methods of identification and make recommendation as to the most practical method of marking. Upon agreement as to the best method of identification other than color, this Sub-Committee shall meet jointly with the Sub-Committee on Classification above mentioned, for the purpose of applying definite markings to the list of materials submitted by that committee.

PART II

In this part of its report the Committee transmitted two important items of information under the heads (*a*) Number of Pipes to be Identified and (*b*) Colors.

(a) *Number of Pipes to be Identified.* It came to the Committee's notice that the number of fluids which need to be identified varies greatly in the various plants. In some only one or two are employed, in others, as many as one hundred are to be found. One chemical plant was found to have twenty-four pipes carrying gases and twenty-three liquids.

(b) *Colors.* The use of red for fire fighting or fire control appears to be

universal, and it is therefore believed that a separate classification for fire-fighting equipment should be made, and that its color should be red, which is at present accepted. In addition to the use of this color for sprinkler lines, it is believed it should be extended to include various pipe lines such as those for Firefoam, etc.

In addition to red, the experience of the members of the Committee is that the following colors are obtainable in permanent or acid-resistant form: black, green, yellow, and aluminum.

In addition to these may be mentioned the possibility of soon obtaining white, gray, and brown.

In view of these conditions and referring to the classifications in the paragraph on Identification, it is suggested that the following be the basic colors for the classification of materials given:

a Safe Products.................Yellow
b Extra valuable materials..........Aluminum
c Dangerous materials.............Black
d Protective materials.............Green
e Fire-control equipment...........Red

Complying with the provisions of the report on Plan and Scope, Chairman Hebble made the following appointments:

F. P. Ingalls or E. J. Cole, *Chairman*, Sub-Committee on Identification by Colors
Crosby Field, *Chairman*, Sub-Committee on Classification
W. S. Morrison, *Chairman*, Sub-Committee on Identification Markings Other Than Color.

Sectional Committee on Colors for Traffic Signals Organized under A.E.S.C. Procedure

THIRTY-NINE men—representing as many administrative bodies, trade associations, scientific or technical societies, and Government departments—make up the Sectional Committee on Colors for Traffic Signals which was organized at a meeting in New York City on November 9 under the auspices of the American Engineering Standards Committee.

The committee elected as its officers the following representatives of the three sponsors for the code: Chairman, Charles J. Bennett, State Highway Commissioner of Connecticut, representing the American Association of State Highway Officials; Vice-chairman, Dr. M. G. Lloyd, representing the United States Bureau of Standards; Secretary, Walter S. Paine, Research Engineer, Aetna Insurance Company, Hartford, Conn., representing the National Safety Council.

The sectional committee by resolution invited the Aeronautical Chamber of Commerce of the United States to participate in the work of the committee. It was also decided at the organization meeting of the sectional committee to appoint a sub-committee to investigate the efficiency of all color signals now in use as traffic signals, and where possible to ascertain the reasons for adopting certain colors for specific uses. This committee will investigate the use of various types of semaphores and silent policemen. Another committee will make an original study of specific colors for definite uses as a check upon previous researches and to establish certain colors for traffic signals. A third committee will study non-luminous signs and signals (excluding luminous signals) and after a thorough research propose signs of definite colors and shapes for highways and also for railroad crossings.

Automobile Headlight Testing Specifications Approved by A.E.S.C.

ONE of the tribulations of the touring motorist—the hopeless attempt to comply with the automobile headlighting regulations of all the states through which he passes on his trip across the continent—will be removed as soon as the various state motor-vehicle departments have all adopted the Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles which has just been approved by the American Engineering Standards Committee.

Even before these specifications had been formally approved by the A.E.S.C., nine of the states indicated that they would adopt the specifications; in three states they are already in effect.

These specifications were submitted to the A.E.S.C. by the Illuminating Engineering Society. This organization and the Society of Automotive Engineers have been appointed joint sponsors for any revision and further development of the code which may be necessary.

NEWS OF OTHER SOCIETIES

Taylor Society

The recent meeting of the Taylor Society was a particularly practical one in that the papers presented at its sessions were chiefly descriptions of actual conditions and problems in various concerns, and that ample time was allowed for discussion on each of them.

The first of the six addresses at the convention, which was held in New York, November 23 and 24, 1922, was by Percy S. Brown, works manager of The Corona Typewriter Company, Groton, N. Y. His address dealt with a specific type of manufacture, the continuous production of portable typewriters, their cases and a few accessories, for which it has been found expedient to departmentalize highly and to standardize operations. The functions of the various departments and their relation to each other were discussed in some detail by Mr. Brown, who also told of research work to develop standard operations. The Corona Company stimulates the interest of its foremen by holding bi-monthly conferences at which the management presents information on sales costs, items of expense, and other matters not usually brought to the attention of foremen, and gives an opportunity for discussion of all major factory problems. Reduction of manufacturing costs by the study of routing operations and precise control through the planning system has been effected to a large degree in the plants of the Corona Company. The discussion upon Mr. Brown's paper was led by L. Herbert Ballou, of the Lewis Mfg. Co., Walpole, Mass., and R. H. Lansburgh, Wharton School, University of Pennsylvania.

Dr. H. S. Person, managing director of the Taylor Society, speaking at an evening session on Thursday, November 23, on Shaping Your Management to Meet Developing Industrial Conditions, reviewed conditions during the last few years and showed the effect of the recent business depression upon various enterprises. He stated as his belief that there are still many difficulties to be met, particularly by those establishments which continue to employ conventional management methods.

Dr. Person said that he did not believe that future conditions could safely be forecasted from the present industrial activity and went on to point out some of the facts which have been learned from studies of business cycles and analyses of industrial conditions. He called attention to the fact that demand is going to be less than the productive capacity and said that the way out for the successful competitor seems to be to develop an inclusive system of management which will more than compensate for high prime costs by cost savings elsewhere, thereby effecting lower factory costs and making possible lower selling prices.

Among his suggestions for the new management Dr. Person emphasized the need of more thought being given to policy and general plans and advocated that definite master plans, budgets, and schedules of operation be devised for a considerable period ahead. Organizations should have units to analyze the market and interpret industrial statistics. Improved production methods should be more generally utilized and advertising should bear on the quality of staple merchandise rather than on the creation of new wants. The coöperation of the personnel is essential and the forceful, acquisitive type of executive should be balanced by the thinking, investigating, planning type.

A session on statistical compilation was particularly welcome as many business organizations seem to find it difficult to determine what statistics are essential and what are non-essential, and to establish a statistical technique which secures results precisely and economically. Harry B. Horwitz and H. J. Hutkin, chief speakers at this session, discussed some of the uses of statistical compilation as a function of scientific management, presenting a description of the organization, methods, results, and equipment of the planning department of the statistical and methods divisions of the Joseph and Feiss Company of Cleveland, with which both are connected.

The methods of the Hood Rubber Co. and those of the Dennison Mfg. Co. in analyzing the market and establishing coördinated schedules of sales production and finance on the basis of that analysis were described by representatives of those companies, W. W. Duncan and E. E. Brooks, respectively.

Philip J. Reilly, associate director of the Retail Research Association, New York, addressed the convention on November 24 on the subject of the reduction of waste through research studies in the

operating departments of retail stores, summarizing the results of recent studies that have been made by his association.

The closing symposium dealt with the supervision of personnel. It reviewed the development of personnel departments and the elimination of many of them during the period of depression following the war, pointing out the durable features of personnel work.

American Society of Refrigerating Engineers

The eighteenth annual meeting of the American Society of Refrigerating Engineers, one session of which was held in conjunction with the A.S.M.E. Annual Meeting, took place in New York, December 4 to 6, inclusive. The opening session was devoted to a business meeting, which included discussions of the Mechanical Refrigeration Safety Code and the Code for Unfired Pressure Vessels. New officers elected at this session were William S. Shipley, Brooklyn, N. Y., president, Van R. H. Green, New York City, vice-president; L. Howard Jenks was reëlected treasurer, and William H. Ross, secretary.

The joint session with the A.S.M.E., held on the afternoon of December 4, included two papers, one on the Economic Thickness of Insulation in the Refrigerating Field, by Percy Nicholls, Pittsburgh, Pa., contributed by the A.S.R.E.; and one on the Design of Cooling Towers, by C. S. Robinson, of the Department of Chemical Engineering, Massachusetts Institute of Technology, contributed by the A.S.M.E.

Mr. Nicholls, who is connected with the Research Laboratory of the A.S.R.E., defined the economic thickness for a heat insulation as that which will reduce to a minimum the sum of the expenses due to the heat passed through it plus the expenses of prevention. He interpreted this definition for such cases as the walls of ice and storage houses, pointing out the factors of monetary expense, and also for tanks, pipes, and cylinders. Mr. Nicholls stated that it was not his purpose to recommend a definite thickness, but rather to establish a standard of reference, and to set forth a basis of argument on which the figuring of the thickness may be done.

In Mr. Robinson's paper it was pointed out that engineers have designed cooling towers in the past on empirical information and in accordance with the experience of previous successful designs. Wide departure from standard designs is difficult because of the lack of scientific basis for the design. Mr. Robinson therefore established the general principle applicable to cooling-tower design and derived equations for the use of the designer. He presented a quantity of experimental data to substantiate the validity of his formulas and showed by an actual experiment how these formulas are applicable to the design of a counter-current cooling tower.

The presidential address, delivered by Harry Sloan of Milwaukee, Wis., retiring president of the society, at an evening session, December 4, was on the subject of educating and training the engineer. Other addresses at this session were by C. S. Cragoe, of the National Bureau of Standards, Washington, D. C., giving the physical properties of ammonia as determined by that bureau, and by H. J. Macintire, Urbana, Ill., on the Flexibility of Cast-Iron Radiators for Direct Expansion of Ammonia.

Two technical sessions were held on the second day of the convention at which four papers were presented and the commercial value of hydrocarbon refrigerants was discussed. George A. Horne, of New York City, described tests made at the Tenth Avenue plant of the Merchants' Refrigerating Co., New York, to determine the horsepower for varying condenser pressures of a single-acting simple ammonia compressor, and tubular condensers. The machine on which the tests were made is a vertical three-cylinder, single-acting, simple compressor of the enclosed type with pistons 18 in. in diameter and a 20-in. stroke. The machine is direct-connected to a synchronous motor and is operated at 164 r.p.m. The condensers are shell and tube, open type, in which the water is pumped over the top and flows through the tubes by gravity into an open pan. The condenser liquid is cooled in a double-pipe liquid cooler from which it passes to a shell-and-tube brine cooler. Mr. Horne's paper contained tables giving test data, power calculations and volumetric efficiencies, condenser calculations and data, and calibrations of the ammonia meter. He called particular attention to this method of measuring the refrigerating output of the compressor, which he said was a distinct refinement over any method of simply weighing or gaging the liquid during the tests.

A paper by W. G. Croll, of Wellington, New Zealand, described the design of several air batteries installed in a plant in southern New Zealand for use in the refrigeration of meat. Desirable features of this method are clean, dry freezing rooms and purer air, and although the first cost is expensive, the power factor is high.

There were also presented at this session papers on the Compresion Refrigerating Cycle, by W. H. Motz, Chicago, Ill., and the Reliability of Fluid Meters in Refrigeration Tests, by L. S. Morse, York, Pa.

The closing technical session was held on Wednesday, December 6, and included papers entitled Heat Waste in Ammonia-Compression Refrigerating Machines, by J. H. H. Voss, New York, and An Oscillating Compressor for Ammonia, by H. J. Macintire, Urbana, Ill., together with discussions of new things in refrigeration and other topics suggested by the membership.

Inspection trips were made to the Tenth Avenue and North Moore Street plants of the American Refrigerating Company, to the Hellgate Station of the United Electric Light & Power Co., and to the Carrier Engineering Corpn., of Newark.

Society of Naval Architects and Marine Engineers

The thirtieth general meeting of the Society of Naval Architects and Marine Engineers was held in New York during American Marine Week, November 8 and 9, 1922. Twelve technical papers were presented, a number of which dealt with subjects of interest to mechanical engineers.

Elmer A. Sperry, president of the Sperry Gyroscope Co., Brooklyn, N. Y., in a paper on Automatic Steering, described the method of operation of the "iron quartermaster" and its auxiliaries. Although best results can be obtained with this instrument, an experienced quartermaster, with the aid of a gyro-compass repeater conveniently located, can obtain a high degree of accuracy in steering. Mr. Sperry also discussed steering by magnetic compass and described separate and unit systems for automatic steering.

Edwin A. Stevens, Jr., vice-president of the Hoboken Land & Improvement Co., showed the results of applying Dyson's method of analysis to propellers of ocean-going merchant vessels. Three groups of ships were considered, namely, single-screw vessels; vessels fitted with two or more screws, the wing screw being carried in struts; and vessels fitted with two or more screws, the wing screws being carried in bosses or spectacle frames.

Results of wake tests performed upon different models by means of a current meter filled with wheels of varying diameter, were given by E. M. Bragg, professor of naval architecture and marine engineering at the University of Michigan. The study showed that any complete system for determining wake values must take account of the diameter of the screw relative to the draft of the ship; the draft of the ship relative to the breadth of the ship; the fore and aft position of the screw; the transverse position of the screw; the vertical position of the screw relative to the keel; and the vertical prismatic coefficient of the ship.

In a paper entitled Some Experiments on Propeller Position and Propulsive Efficiency, Rear-Admiral David W. Taylor, U. S. N., enumerated the factors affecting hull efficiency and described experiments upon a single-screw low-speed vessel to determine the propeller position.

A. D. Stevens, naval architect and consulting engineer, Jacksonville, Fla., gave a description of how a Government sub-chaser was converted into a 1650-hp. gasoline fire boat for Jacksonville.

Prof. William Hovgaard, Massachusetts Institute of Technology, presented a paper containing a brief description of the principal features of a ship of the Zeppelin type. He also took up the problem of the calculation of stresses and compared the method of transverse shears and of bending moments, giving reasons for the superiority of the latter method.

Points to be considered in the selection of propelling machinery from the point of view of the ship owner were given by J. L. Ackerson, vice-president of the Merchant Shipbuilding Corporation, Chester, Pa. Reliability, economy in operation, and weight were the factors emphasized.

The fact that the Second Annual Marine Exposition was held in New York during the week of November 4–11 gave those attending the convention an opportunity to see the latest developments in hull construction, propulsion machinery, particularly the Diesel

engine, and safety devices, and such modern equipment as the radio direction finder, the mechanical quartermaster described in Mr. Sperry's paper on Automatic Steering, and sounding apparatus.

NATIONAL PERSONNEL ASSOCIATION

The first annual convention of the National Personnel Association was held at Pittsburgh, Pa., November 8–10, 1922. This association was recently formed through the merger of the National Association of Corporation Training and the Industrial Relations Association of America.

Immigration was a principal topic of the convention. The effect of existing immigration laws on labor and industry, training immigrant workers, the social and economic effects of our immigration policy, and the immigrant's point of view were subjects discussed. Among the speakers were Michael I. Pupin, professor of electromechanics, Columbia University, and Magnus W. Alexander, managing director of the National Industrial Conference Board.

The Committee on Trade Apprenticeship Progress recommended that a system for developing sufficient training courses be centralized under a national organization that would embody representatives from the manufacturing, educational, and publishing institutions, and sub-organizations to introduce and supervise the work in different sections throughout the country.

The report of the Committee on Employment and Labor Turnover emphasized the need for coöperation between employment and operating departments, and for careful consideration on the part of the management in hiring, training, and discharging employees.

The Committee on Economics for Employees reported on an investigation of methods of training in industrial economics, touching particularly on the gathering of data illustrating the economic principles as they are working out through the various jobs and every-day relationships of the employee with his job, his fellow-employees, with the firm, and with his employers.

The Committee on Shop Training, headed by R. L. Sackett, dean of engineering, Pennsylvania State College, presented a report calling attention to the shortage of skilled workmen and outlining different types of training.

Discussing the development of men for executive positions, a committee headed by C. R. Dooley, manager of personnel and training, Standard Oil Company of New Jersey, said that "companies having had training courses for several years invariably report that the effort and expense involved are justified by the results."

The report on foreman-training methods stated that foremanship training to be really effective must be a continuous process, and prophesied that the work of the next few years will be not so much the development of new methods as better application of the methods already outlined to the conditions for which they are best suited.

The Committee on Personnel Problems of Small Offices reported that the chief fact discovered "is the almost total lack of a definite, planned training program in the majority of companies. Training in small offices has been left to take care of itself."

An especially important report was that on relations with engineering colleges, prepared by a committee of which W. E. Wickenden, American Telephone & Telegraph Co., New York, is chairman. The report enumerates ways and means by which assistance, through the Personnel Association, can be rendered by industries to engineering colleges.

Reports were also heard on health education, pensions for industrial and commercial employees, employee publications, and industrial and public-school relations, industrial motion pictures, and job analyses.

Other addresses at the convention were by W. W. Kincaid, Niagara Falls, president of the Association, on Nationwide Coöperation in Personnel Work, and by E. K. Hall, vice-president of the American Telephone & Telegraph Co., on Management's Responsibility for and Opportunities in the Personnel Job.

Inspection trips were made during the convention to the East Pittsburgh works of the Westinghouse Elec. & Mfg. Co., the Duquesne works of the Carnegie Steel Co., the Colfax power plant of the Duquesne Light Co., the American Window Glass Co., Arnold, Pa., and the Mellon Institute of Industrial Research of the University of Pittsburgh.

Lincoln New Dean of Electrical Engineering School of Cornell University

PAUL M. LINCOLN

On November 1, 1922, Paul M. Lincoln assumed his duties as director of the electrical engineering school of Cornell University, replacing Prof. Alexander Gray who died some months ago. Since 1919 Mr. Lincoln has been associated with the Lincoln Electric Co., organized by his older brother in 1904. Mr. Lincoln was graduated in 1892 from Ohio State University with the degree of M.E. in E.E., and then entered the employ of the Short Electric Co., Cleveland, Ohio. Later he was connected with the Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa., and after two and a half years with that concern became electrical superintendent of the Niagara Falls Power Co., Niagara Falls, N. Y., where he was located for seven years. In 1902 he returned to the Westinghouse Co., where for about seven years he had charge of the power division of the engineering department. In 1910 he was appointed a general engineer with the company and remained with them until 1919, when he resigned to become associated with the Lincoln Electric Co. From 1911 to 1915 Mr. Lincoln acted as head of the electrical school of the University of Pittsburgh, while still carrying on his work with the Westinghouse Co.

Mr. Lincoln is a member of both the A.S.M.E., and the A.I.E.E., and was president of the latter society in 1914. In 1902 he invented the synchroscope, for which he was awarded the John Scott Medal by the City of Philadelphia on recommendation of The Franklin Institute.

Boston Gives M.I.T. Students Unusual Opportunity

STUDENTS at the Massachusetts Institute of Technology have been given an opportunity to assist in solving some of Boston's municipal problems in a recent offer made by that city through its mayor, James M. Curley. Four prizes of $500 each will be given for the best reports and working plans for solving certain problems connected with street traffic, street cleaning, malodorous and unsanitary nuisances, and fire-protective building construction.

The competition is open to any student enrolled at M.I.T. in 1922–1923 and is to be concluded May 1, 1923. The conditions of the contest stipulate that the recipients of such prize awards relinquish full rights, without further payments, to the use of the devices or methods proposed. One judge is to be selected by the mayor, one by the head of the Department of Civil and Sanitary Engineering at the Institute, and the third by the two so selected.

Chinese Board Specifies A.S.M.E. Boilers

In a recent communication Mr. Wm. Althoff, Asst. Chief, Industrial Machinery Division of the Department of Commerce, Washington, D. C., states that the Department has received copies of specifications for tenders invited by the Min River Conservancy Board, Foochow, China, for a steam-operated river-type hydraulic dredge for improving the channel of the Min River; tenders to be in the hands of the Board not later than February 15, 1923. These specifications include the following clauses:

> *Boiler.* The boiler shall be constructed in accordance with the specifications of the Boiler Code Committee of the A.S.M.E.—or other equivalent specifications.
>
> *Hull.* The steel used in the hull shall meet the requirements of the specifications for structural steel for ships of the American Society for Testing Materials—or other equivalent specifications.

The Min River Conservancy Board, although a Chinese Government organization is, through their representation on it, under the virtual power and control of the commissioner of customs and the foreign consular representatives and representatives of foreign commercial bodies. Its funds are supplied by a surtax on the regular customs tariff and the funds are administered by the Board though collected by the customs. The engineer in chief is an American.

LIBRARY NOTES AND BOOK REVIEWS

American Malleable Cast Iron. By H. A. Schwartz. First edition. Penton Publishing Co., Cleveland, Ohio, 1922. Cloth, 6 × 9 in., 416 pp., illus., diagrams, $7.

This book, the only American one on the subject now in print, is the work of a metallurgist with long experience in the industry. The volume opens with a historical account of the development of the malleable industry in the United States from its inception in 1820. The various phases of manufacture are then discussed, including the plant, materials, fuels, refractories and melting practice with air, electric, cupola and open-hearth furnaces. Succeeding chapters treat of annealing, molding and pattern-making, cleaning, finishing, inspecting and testing. The final section of the book is a study of the physical, thermal and electrical properties of malleable castings, in which is given much hitherto unpublished material. A selected bibliography of nearly 200 references is given.

A.S.T.M. Tentative Standards. 1922. American Society for Testing Materials, Philadelphia, 1922. Cloth, 6 × 9 in., $8.

The 1922 issue of tentative standards contains 163 specifications for engineering materials, such as metals, cement, lime, gypsum and clay products, preservative coatings, petroleum products, road materials, coal and coke, waterproofing, insulating materials, containers, rubber goods and textiles. These specifications are tentative, that is, they are distributed prior to definite adoption, for the purpose of eliciting criticism.

Anthracite and the Anthracite Industry. By A. Leonard Summers. Isaac Pitman & Sons, New York, 1922. (Pitman's Common Commodities and Industries.) Cloth, 5 × 7 in., 126 pp., illus., map, $1.

A brief non-technical account of anthracite mining, and of the advantages of anthracite as a fuel, with special reference to British conditions.

Belt Conveyors and Belt Elevators. By Frederic V. Hetzel. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 333 pp., illus., diagrams, tables, $5.

This book, the author says, is not a mere restatement of trade literature nor a collection of descriptions of installations of conveying and elevating machinery. It aims rather to explain principles and the reasons for doing things. The present volume deals with belt conveyors and belt elevators, and uses these machines, which are so widely useful, to illustrate some of the general principles that underly the design and use of conveying and elevating machinery. The author has had thirty years' experience in the design, manufacture and erection of machinery of this kind.

Berechnen und Entwerfen von Turbinen-und Wasserkraft-Anlagen By I. Holl. Third edition. R. Oldenbourg, Munich, 1922. Paper, 7 × 10 in., 181 pp., illus., 225 mk.

Holl's Calculation and Design of Turbine and Water-Power Plants was written with the intention to furnish all who are interested in water-power plants with a convenient assistant in solving the various problems that arise in calculation and design. To facilitate calculation, the author invented a turbine slide rule, the use of which is explained in this book.

In this edition, which is thoroughly revised, the book is planned to give the designer a concise introduction to all the structural and mechanical details of water-power plants, which will not only enable him to determine the turbine system for any projected plant, but will also give information upon the construction required in connection therewith.

Dyke's Automobile and Gasoline Engine Encyclopedia. By A. L. Dyke. Thirteenth edition. Goodheart-Willcox Co., Chicago, 1922. Cloth, 7 × 10 in., 1226 pp., illus., $6.

The new edition of this well known reference and instruction book has been entirely rewritten and rearranged. The number of pages has been increased from 960 to 1238, and the illustrations from 3362 to 4143. Intended for owners, repair men and students, the book is a remarkably comprehensive compendium of information on automobile construction, operation and repair.

Electric Power-Plant Engineering. By J. Weingreen. Third edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in., 511 pp., illus., diagram.

Intended to provide information on practical problems connected with the control of the generation and distribution of electrical energy. Theoretical discussions are reduced to a minimum, the book being primarily a record of current American practice in power-plant engineering. This edition has been thoroughly revised. New material has been added on oil switches, open-air switches, lightning arresters and outdoor sub-stations, and reactive coils and synchronous condensers have been discussed in greater detail.

Elektrische Oefen. By Oswald Meyer. Vereinigung Wissenschaftlicher Verleger, Berlin and Leipzig, 1922. Boards, 4 × 6 in., 133 pp., illus., $0.30.

This little book opens with a short historical review of electric-heating processes. Next are discussed the physical foundations, methods of measuring furnace temperatures, structural elements and materials for electric furnaces. This is followed by a chapter devoted to the various types of furnaces, classified by methods of heating. The remaining chapters discuss the use of electric furnaces in various industries, domestic electric apparatus for heating and cooking, electric boilers, etc.

Handbook of the National District Heating Association. D. L. Gaskill, Sec'y-Treas., Greenville, 1921. Fabrikoid, 5 × 7 in., $5.

Prepared by the Educational Committee of the Association, and intended as a working manual of district-heating practice, particularly with respect to engineering problems. The material is published in loose-leaf form, arranged in two general divisions, Steam and Hot-Water Heating. Each of these divisions is subdivided into the following groups: General, Generation, Distribution, Utilization, Metering. In addition to engineering data, commercial information supplied by manufacturers of apparatus is included.

Hütte. Hilfstafeln zur I. Verwandlung von Echten Bruchen in Dezimal-Bruche. II. Zerlegung der Zahlen bis 10,000 in Primfaktoren. Third edition. Edited by the Akademischen Verein Hütte. Wilhelm Ernst & Sohn, Berlin, 1922. Paper, 5 × 8 in., 83 pp., tables, 2 mks.

Two convenient mathematical tables, for the use of calculators and designers are given in this little book. Table I is a series of common fractions arranged in an increasing series and accompanied by their decimal equivalents, calculated to eleven places. It can be used to translate any decimal fraction into a common fraction, neither term of which will be greater than 100. Table II gives the simplest factors of all numbers not divisible by 2 or 5, from 1 to 10,000 and also shows the prime numbers in this range.

The tables are intended primarily for determining gear ratios for lathes, milling machines, etc., but are adapted for other uses as well. Examples of their use for various purposes are given.

Manufacture and Uses of Abrasive Materials. By Alfred B. Searle. Isaac Pitman & Sons, New York, 1922. (Pitman's Technical Primer Series.) Cloth, 4 × 6 in., 118 pp., illus., $0.85.

Brief description of abrasive materials and their preparation and of the manufacture of abrasive wheels, papers and polishes, together with advice upon the selection and testing of abrasives, and the erection and operation of grinding machines. Should be useful to those called upon to deal with grinding problems without any very extended experience in the art.

Manufacture of Dyes. By John Cannell Cain. Macmillan & Co., New York, 1922. Cloth, 6 × 9 in., 274 pp., $4.50.

This volume seems intended as a supplement to the author's earlier work, The Manufacture of Intermediate Products for Dyes. It describes methods for making a large number of commercial dyes,

giving details of the processes and referring to the English, American, French and German patents concerned, as well as to descriptions in books and periodicals.

Theory of Wave Transmission. By George Constantinesco. Second edition, revised. Walter Haddon, London, 1922. Cloth, 5 × 9 in. 209 pp., tables, 10s. 6d.

A detailed mathematical exposition of the theory underlying the method of power transmission invented by the author. In this system energy is transmitted from one point to another by means of periodic variations of pressure which produce longitudinal wave pulsations in a column of liquid enclosed in a system of piping connecting the wave generator and the tool or machine. Many advantages are claimed for the method, which has been applied practically to rock drills and other percussive tools and to trigger control in machine guns, and is now being adapted to the production of rotary motion.

Treatise on Bessel Functions. By Andrew Gray and G. B. Mathews. Second edition. Macmillan & Co., London, 1922. Cloth, 6×9 in., 327 pp., $12.

This book has been written in view of the great and growing importance of the Bessel functions in almost every branch of mathematical physics; and its principal object is to supply in a convenient form as much of the theory of functions as is necessary for their practical application, and to illustrate their use by a selection of physical problems, worked out in some detail. This new edition has been thoroughly revised. The earlier chapters have been rewritten, examples have been appended and additions have been made to the tables. A bibliography is included.

Welding Encyclopedia. By L. B. Mackenzie and H. S. Card. Second edition. Welding Engineer Publishing Co., Chicago, 1922. Fabrikoid, 6×9 in., 388 pp., illus., tables, charts, $5.

A reference book on the theory, practice and application of the four processes for autogenous welding. The first half of the book is a dictionary of the words, terms and trade names used in the industry. Included in this are instructions for the common types of repair and production work, descriptions of tests, specifications for rods and wires, and descriptions of the application of welding in various industries. Following the dictionary are separate chapters on the four processes for welding, giving detailed descriptions of each and instructions for its use. Chapters on boiler tank, pipe and rail-joint welding are then given, followed by a section on the regulations of federal and state authorities, and insurance companies, and a chapter on the heat treatment of steel. A collection of charts and tables and a catalog section are also provided.

TESTING INVOLUTE SPUR GEARS

(Continued from page 34)

ing gears. No matter how accurately a gear may be cut, if it is carelessly forced or keyed on its shaft or if the shafts are not in line in both planes, satisfactory operation cannot be obtained.

Discussion

B. F. Waterman[1] submitted a written discussion in which he said that the reason gears had not been inspected with quite the precision employed in the case of other and simpler pieces, was because gears were not the easiest pieces of mechanism to understand and measure.

In most shops if a pair of gears was noisy it was immediately assumed that the cutter was not right or, if the cutters had cut other gears that had run quietly, that the gear-cutting machine was at fault, when it was probably neither of these but rather carelessness on the part of the operator in setting up the machine, and perhaps improper mounting of the gears or, last but the least considered, the design of the gears or the machine upon which they were finally mounted to run.

If, however, proper care was taken in using the machines and cutting tools, and means were at hand for testing the gears, much trouble could be avoided. In all up-to-date shops an effort was made to check the first pair of gears taken off the cutting machine and, if they were not correct, steps could be taken to correct the trouble in so far as the gears were concerned.

In most shops the gear-testing machine first mentioned in the paper was sufficient, as it was a very easy one to use.

The Saurer machine seemed to have considerable merit and undoubtedly would find a place in many gear shops, but it was perhaps too exacting for most gears. With gears, as with everything else used in machinery, tolerances of greater or less degree had to be employed, and in most cases they were sufficiently great to make the use of charts unnecessary.

Charles H. Logue[2] wrote that the study of irregularities in pitch-line velocities was a study of the entire gear problem, and the paper was therefore of vital importance.

It might be claimed that there was little use in locating and measuring errors in the formation of gear teeth—that what was required was a means for producing gears free from error. The fact of the matter was that there was little chance for securing the means by which more perfect gears might be produced, until the nature of the errors encountered could be located, measured and understood. This must serve as a guide in the production of better cutters and hobs, as well as in the design of the teeth themselves. Again, to attain the highest quality or to maintain any uniform quality with the means at hand, facilities must be immediately available for a measurement of quality. In all other branches of machine-shop practice this was a recognized principle: it was only in the cutting of gear teeth that this principle was ignored.

The testing machine described by Mr. Estabrook furnished a definite means by which the accumulative error of a *pair of gears* might be measured, leaving no opportunity for a difference of opinion as to relative operating quality.

The service which might be expected of a pair of gears depended primarily upon their operating quality, or upon the correctness of the formation and spacing of the teeth. The trade, sooner or later, would specify this quality and accept or reject gears on percentage of error in pitch-line velocities—that is, they would ask for a definite measure of attainment.

Earle Buckingham[3] said that an inspection had two prime purposes: First, to see that the manufacturing facilities and processes were sufficiently accurate and reliable to produce the desired results; second, to test the results actually obtained—to sort out the good work from the bad. To test the tools required a great variety of equipment, which in many cases was laboratory equipment. Any facilities for testing the product itself should be extremely simple. The so-called feeler test was an extremely good one when the man who gave it understood what he was doing; but after he had sorted the good from the bad, he knew but very little as to why the bad ones were bad. That was where the more elaborate laboratory instruments came in.

F. E. Cardullo[4] said that after a gear had been tested by all of the processes which had been described, there still remained to be dealt with gears which were noisy. He believed that a part of the noise might be attributed to the fact that in the action of the gear during the angle of approach the effect of friction between the teeth was to increase the pressure angle, but after the recess the effect was to reduce the pressure angle. That meant each time the tooth passed the center line, there would be an alteration to some extent in the amount, and to a considerable extent in the direction, of the forces acting between the teeth.

Now, if these forces, which were absolutely independent of the form of the gear, were dependent only on the smoothness of action and the quality of lubrication, fell into natural synchronism with any of the natural vibration periods of the body in which the gear was mounted, a noisy set of gears would result, no matter how perfect the forms of the teeth and all the other features might be. He believed that a great many mysterious gear troubles had been due to something of that nature. There was a very wide field still for investigation in the action that went on in a pair of running gears, and the possibilities of trouble.

[1] Designer, Brown & Sharpe Mfg. Co., Providence, R. I. Mem. Am. Soc.M.E.

[2] Consulting Engineer, Syracuse, N. Y.

[3] Engineer, Pratt & Whitney Co., Hartford, Conn. Mem. Am.Soc.M.E.

[4] Chief Engineer, G. A. Gray Co., Cincinnati, Ohio. Mem. Am.Soc.M.E.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 137-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

All-Metal. The Modern Airplane and All-Metal Construction, William B. Stout. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 495–500 and (discussion) 500–504, 11 figs. Outline of structural problems followed by progress of development of thick-wing and all-metal airplanes with which author has been identified. Author believes that future commercial airplanes will have all-metal construction.

ALLOYS

Light. Some Points of Contact Between Metallurgy and Engineering, Owen W. Ellis. Eng. Jl. (Eng. Inst. of Canada), vol. 5, no. 12, Dec. 1922, pp. 576–581, 1 fig. Early development of iron and steel industry; research on alloys; economics of alloys of aluminum for structural work; composition and mechanical properties of duralumin; tests on a duralumin channel; important alloys recently investigated; possibility of use of light alloys in structural field.

AUTOMOBILE ENGINES

Moderate vs. High-Speed. The Low-Compression Low-Speed Engine for Motor Vehicles, F. Strickland, and The High-Compression High-Speed Engine for Motor Vehicles, H. R. Ricardo. Engineering, vol. 114, no. 2968, Nov. 17, 1922, pp. 627–630, 8 figs. Contributions to debate before Instn. Automobile Engrs. See also Automotive Industries, vol. 47, no. 22, Nov. 30, 1922, pp. 1079–1081.

Reciprocating Parts, Light-Weight. Advantages of Light-Weight Reciprocating Parts, L. H. Pomeroy. Soc. Automotive Engrs.—Jl. vol. 11, no. 6, Dec. 1922, pp. 508–515 and (discussion) 515–519, 1 fig. Influence of weight of reciprocating parts on chassis in general and engine in particular is emphasized as being of greater importance than actual saving in weight of parts themselves; tabulation of specific strengths of various materials used in automotive engineering shows advantages of aluminum as compared with steel; comparison of steel and aluminum connecting rods; advantages of using aluminum in connecting rod to secure stiffness.

BOILER PLANTS

Improvements. Plant Improvement Shows Large Saving. Power, vol. 56, no. 21, Nov. 21, 1922, pp. 790–794, 11 figs. Changes at plant of Int. Motor Co. made it possible for three boilers operating at 200-per cent rating to do work of eight used originally; large saving was effected by doubling evaporation per lb. of coal, resulting from change of boiler baffling and application of hand stokers. Plant, instead of consuming 50 tons of coal daily, averaged 50 tons last winter.

BOILERS

Electrically Heated. Electric Steam Boilers for Using Surplus Water Power. Elec. World, vol. 80, no. 23, Dec. 2, 1922, pp. 1211–1212, 3 figs. High efficiency, negligible attendance, small floor space and flexibility of operation claimed for electrically heated boilers; relative merits with essential requirements; three methods of heating water are available, indirect, direct and electrode system. Based on information from Hackethal Nachrichten.

CASTING

Centrifugal. Casting Steel Ingots Centrifugally, L. Cammen. Iron Age, vol. 110, no. 23, Dec. 7, 1922, pp. 1494–1496, 3 figs. Results from using horizontal bottle-neck mold; comparison with earlier attempts; excellence of ingots and their cost.

CRANES

Traveling. 100-Ton Overhead Electric Traveling Crane. Engineer, vol. 134, no. 3491, Nov. 24, 1922, p. 562, 3 figs. partly on p. 554. Four-motor electric crane, capable of lifting 100 tons, constructed for Japanese Navy by Vaughan Crane Co., Manchester, England.

CYLINDERS

Automobile Engines. Ford Engine-Cylinder Production, P. E. Haglund and I. B. Scofield. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 463–471, 21 figs. Principles governing intensive quantity production; sources and methods of handling basic materials that compose Ford engine cylinder; fundamental plan of River Rouge plant.

DIE CASTING

Developments. Developments in Die-Casting Practice, Charles Pack. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 281–283, 3 figs. Die-casting dies; location of parting line; draft required in dies for castings made from different alloys.

Equipment. Equipment for Making Die-castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 261–263, 5 figs. Applications of die castings; general principles of die-casting machines; points on design of parts to be die-cast.

EVAPORATORS

Flash. The Flash Evaporator. Power, vol. 56, no. 22, Nov. 28, 1922, pp. 834–835, 3 figs. New type of apparatus for producing distilled makeup water.

Triple-Effect. How a Lillie Evaporator Operates. Power, vol. 56, no. 21, Nov. 21, 1922, pp. 802–804, 3 figs. Operation of triple-effect evaporator that operates on exhaust steam.

FOREMEN

Duties. The Rightful Place of the Shop Foreman, A. H. Rodrick. Indus. Management (N. Y.), vol. 64, no. 6, Dec. 1922, pp. 350–351 and 354. Tells how shop foreman can become most valuable link in management chain.

Training. Training Steelworks Foremen, B. M. Nussbaum. Iron Trade Rev., vol. 57, nos. 21 and 22, Nov. 23 and 30, 1922, pp. 1407–1408 and 1491–1492. Points out that management should participate in training; instruction and fundamentals of industrial management given in iron and steel industry with successful results; club idea failed.

FREIGHT HANDLING

"Veri-Direct" Method. The "Veri-Direct" Method of Handling L.C.L. Freight. Ry. Age, vol. 73, no. 23, Dec. 2, 1922, pp. 1053–1057, 6 figs. Method of loading freight from freight houses into cars in use in Ohio region of Erie R. R., which has reduced errors and losses due to wrong loading about 70 per cent as compared with former conditions.

FURNACES, ANNEALING

Continuous. Continuous Annealing Furnaces for Sheets. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1342–1343, 3 figs. Car-type furnaces with daily capacity of 125 tons each at Ashtabula steel plant; pulverized coal used as fuel. See also article by E. L. Shaner in Iron Trade Rev., vol. 71, no. 21, Nov. 23, 1922, pp. 1423–1427, 8 figs.

GAS PRODUCERS

Mechanically Agitated. The Stein-Chapman Gas Producer with Mechanical Agitator. Engineering, vol. 114, no. 2967, Nov. 10, 1922, pp. 597–598, 8 figs. Embodies Chapman floating agitator and new form of automatic ash extractor.

GEARS

Involute Curve. The Law of the Involute Curve, O. G. Simmons. Am. Mach., vol. 57, nos. 21 and 22, Nov. 23 and 30, 1922, pp. 801–803 and 837–839, 6 figs. Determining lead of involute curve; how right- and left-hand involutes may be generated; finding length of involutes; developed principles applied to generating gear teeth; adapting milling machine to cutting gear teeth with true involute.

HOBBING MACHINES

Testing. Testing Gear-hobbing Machines, D. Vaughn Waters. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 304–306, 5 figs. Testing fixtures used by Gould & Eberhardt, Newark, N. J.

HOBS

Manufacturing. Simmons Method of Hob Making, Charles O. Herb. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 255–260, 11 figs. Method of simultaneously generating and relieving teeth of gear hobs with revolving cutter resembling spur gear.

INDUSTRIAL MANAGEMENT

Instructions, Illustrated. Illustrated Instructions, Joseph Spielvogel. Management Eng., vol. 3, no. 6, Dec. 1922, pp. 365–369, 5 figs. Shows how, by use of illustrations in connection with such items as assembly drawings, bills of materials, stock, estimating, inventory and cost records, etc., it is possible to apply quantity production principles to manufacture of complicated machinery during plastic stage of development.

Tool Purchasing and Storage. Ordering and Storing Small Tools, W. J. Sansom. Am. Mach., vol. 57, no. 23, Dec. 7, 1922, pp. 869–872, 4 figs. Things to do and to avoid in ordering small tools; inspection and storage methods; systems of getting tools to workmen.

LATHES

Semi-Automatic Multi-Cut. New Semi-Automatic Multi-Cut Lathe, William O. Strauss. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 276–278, 4 figs. Machine developed by R. K. LeBlond Machine Tool Co., Cincinnati, turns work up to 12 in. in diam. and is made in various bed lengths giving max. center distances of 18, 26, 34, or 42 in.

LOCOMOTIVES

Power Reverse Gear. All-Service Locomotive Power Reverse Gear. Ry. Age, vol. 73, no. 23, Dec. 2, 1922, pp. 1051–1052, 4 figs. New non-creeping power reverse gear equally adapted to passenger, freight or switching service. Designed by Transportation Devices Corp.

MACHINE TOOLS

Selection. Selection of Machine-Tools, A. J. Baker. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 520–528. Investigates problem of determining when to make change of equipment by substituting new machine tools for old, or special machines for standard.

Standard. Standard Machines Increase Production, L. S. Love. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1335–1338, 9 figs. Savings effected in use of fixtures rather than in special machines; case of quintupled production. Changes made in production-plant layout at Gray & Davis Division of Am. Bosch Magneto Co.

Standard vs. Special. Standard versus Special Machine-Tools for Automotive Production, R. K. Mitchell. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 472–473. Points out disadvantages attending use of special machines and benefits of using standard equipment whenever possible; possibilities of special jig-and-fixture design that would meet needs of manufacturers of standard parts.

METALS

Behavior under Stress. A Mechanical Model Illustrating the Behavior of Metals under Static and Alternating Loads, C. F. Jenkin. Engineering, vol. 114, no. 2968, Nov. 17, 1922, p. 603, 3 figs. Model is said to be capable of illustrating most of phenomena which metals exhibit when tested in any way under mechanical stresses not exceeding their yield points.

NICKEL-CHROME STEEL

Segregation. Ingot Corner Segregation in a Nickel Chrome Steel, T. Henry Turner. Engineering, vol. 114, no. 2969, Nov. 24, 1922, pp. 662–664, 9 figs. Experiences encountered in examination of large and medium-sized steel forgings which had been received for machining at some of most important engineering works in England. Paper read before Staffordshire Iron & Steel Inst.

POWER PLANTS

Economy in. The Cost of Power Per $100 of Pay-Roll, P. F. Walker. Management Eng., vol. 3, no. 6, Dec. 1922, pp. 339–342. Discusses economizing in power by (1) saving in fuel through greater efficiency at source, and (2) saving by eliminating losses in transmission and application within establishment.

PULVERIZED COAL

Equipment. Rochester Plant Installs Pulverized Fuel Burning Equipment, R. D. DeWolf. Power, vol. 56, no. 22, Nov. 28, 1922, pp. 845–847, 2 figs. Furnaces of two 8750-sq. ft. boilers converted to burn pulverized fuel; pulverizing equipment and coal bins located directly above boilers; no conveyors or driers used; one operator handles both boiler and pulverizer.

Power Plants. Modern Industrial Plant Burns Pulverized Coal. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 868–874, 8 figs. New plant of Eline's, Inc., Milwaukee, contains complete fuel-preparation plant; special ventilation of furnace walls; economizers and hot-process water-softening system.

RAILWAY MOTOR CARS

Requirements and Future of. Motor Cars on Rails. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 481–490, 5 figs. Contains following papers: The Field for the Rail Motor-Car, Roy V. Wright; Some Requirements for the Rail Motor-Car, W. L. Bean; Automotive Rail-Cars and Their Future Development, L. G. Plant.

REFRIGERATING PLANTS

Equipment Specifications. Value of Specifications in Purchasing Refrigerating Equipment, A. C. Bishop. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 884–886. Paper read before Nat. Assn. Practical Refrig. Engrs.

STEAM ENGINES

Standard Extraction. Tandem Extraction Engine for Combined Power Production and Exhaust Steam Heating. Engineering, vol. 114, no. 2967, Nov. 10, 1922, pp. 584–585, 5 figs. partly on p. 558. Tandem compound engine, in which steam required for heating purposes is drawn from receiver between two cylinders.

Uniflow. Unaflow Valve Gear of American Design. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 880–881, 6 figs. Describes several valve gears used on Filer & Stowell uniflow engines. Method of setting valves.

STEEL

Carbon, Manganese Effect on. Effect of Manganese on Carbon Steels, Henry S. Rawdon and Frederick Sillers, Jr. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1357–1361, 7 figs. Their structure as affected by varying percentages; manganese as strengthening factor in low and medium steels. Published by permission of Bur. of Standards.

STEEL, HEAT TREATMENT OF

Case-Hardened Articles. Heat Treatment of the Core of Case Hardened Articles, H. B. Knowlton. Forging & Heat Treating, vol. 8, no. 11, Nov. 1922, pp. 526–528, 5 figs. Study of effect of carburizing heat upon core and of structure and strength of article carburized after various heat treatments.